The Investigation of Edge Effects Within Fragmented Forest Islands in Short Hills Provincial Park

by

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ABSTRACT

It has been well documented, within the field of landscape ecology, that terrestrial fragmentation contributes to increased heterogeneity at the landscape level. It has also been observed that elevated areas of edge habitat occur within fragmented landscapes. Spatial and temporal edge effects were investigated in four areas designated as Nature Reserve Zones within Short Hills Provincial Park, near St. Catharines, Ontario.

Random sampling along exposed edges was performed on trees and saplings, at 5 and 25 m edge depths, using the point-centred quarter method. Diameter at breast height (dbh) and distance from point measurements were used to establish relative density, dominance, frequency and importance value. One-way analyses of variance were used on dbh measurements of tree species and Chi-Square contingency tables were used on size class distributions of saplings species to determine significant differences between 5 and 25 metres. Qualitative comparisons of importance values were also used to determine differences between 5 and 25 metres as well as between trees and saplings.

These statistical and qualitative comparisons suggest that a significant overall **spatial edge effect** is currently exhibited by fragmented wooded islands within the park. The major species of the park, *Acer saccharum*, may be exhibiting a **temporal edge effect**. The heterogeneous nature of the park may be of importance in understanding this area as a complex, ecological system. It is possible that the remaining forest tracts of the park have been affected, and continue to be affected by previous disturbances.

Based on these findings, recommendations are made to the Ontario Ministry of Natural Resources concerning the management of Short Hills Provincial Park in accordance with their 1990 proposed Management Plan.

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Lastly, I regret the manner in which this thesis culminated. I believe that I have always been a competent and hardworking student during my career at Brock. It is a pity that several people whom I have previously had great respect and affection for, forgot that at the end.

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INTRODUCTION

Large scale pristine wilderness areas have formed the basis for many studies of ecological systems in the past. However, it has become increasingly difficult to find any ecosystem type on earth which has not been modified to some extent by humans. As a result, spatial heterogeneity is common for most currently observed landscapes (Merriam, 1988). Such landscapes reflect a number of ecosystem types and have largely replaced relatively homogeneous systems over much of the earth's surface.

The concept of heterogeneity is the basis for the scientific field of landscape ecology. As human disturbance of ecosystems continues, the origin and role of heterogeneity gains importance. The task of landscape ecologists is therefore to gain knowledge of the relationships between the "building stones" of a landscape and, from these, about the functioning of the landscape as a system. Such knowledge may be utilized as a basis for land management (Zonneveld, 1988).

There is a consensus among landscape ecologists regarding the fundamental importance of landscape heterogeneity. In order to adequately assess the workings of a heterogeneous landscape it has been proposed that there be three levels of approach taken: "1. structural approach (e.g. how objects such as species, energy and nutrients are distributed in relation to sizes and numbers of landscape elements present), 2. functional approach (e.g. building upon the structural approach, the interactions or the flow of objects between elements is explored), and 3. dynamic approach (e.g. the changes in the structure and function of the landscape over time are examined)" (Zonneveld, 1990).

Spatial heterogeneity is often observed within the farmland landscapes of Ontario where human impacts are widespread and evident. Such landscapes are often mosaics of fields, forest islands, roads and buildings. Short Hills Provincial Park in the Region of Niagara represents such a mosaic as active and abandoned farmland patches, forest fragments, roads, buildings and utility corridors, all exist within its borders. Its fragmented nature therefore provides an excellent opportunity to study the impacts of

human disturbance on remnant forest areas. A particular fragmentation impact which has often been studied in forest islands centers on the presence of increased areas of edge habitat (e.g. where two or more vegetation types meet - Smith, 1986). The amount of edge habitat observed in a landscape is often dependant on the severity of forest fragmentation. If fragmented forest islands are of insufficient size to maintain pre-disturbance habitat (i.e. interior or mesic habitat), it is possible for such islands to be composed of essentially "all edge" (Levenson, 1981; Ranney et al., 1981). Organisms (both flora and fauna) may respond in various ways to the environmental conditions created by enlarged edge areas; the production of such responses is due to what is commonly termed the "edge effect" (Smith, 1986). The edge effects experienced by flora and fauna may be spatial (e.g. organisms may differ in size, distribution, and density in the interior as compared to in the edge of forest islands) or temporal (e.g. the importance of a particular organism may increase or decrease over time relative to other species as a result of increased edge habitat). This study investigates whether or not the woody vegetation of several forest islands of Short Hills Park are experiencing spatial and temporal edge effects. If so, this may suggest that the structure, function and dynamics of the park's vegetation is significantly affected by the heterogeneous nature of its landscape.

Landscape Concept

The word 'landscape' evolved from the Dutch and German words 'landschap' and 'landschaft' (Troll, 1971; Neef, 1982; Zonneveld, 1988 and 1990). Dictionary definitions of it include: (a) "a picture representing natural inland scenery" and (b) "an expanse of natural scenery seen in one view" (Webster's New World Dictionary, 1963). Academically, the landscape concept has been viewed from a variety of standpoints such as aesthetic, professional, cultural, physical landform or artistic (Forman and Godron, 1986).

The first academic use of the landscape concept was by nineteenth-century geographers in which the study of the relationship between the earth's physical environment and human actions was emphasized (Forman and Godron, 1986). In more recent times the concept of heterogeneity has been proposed as an integral component in any description of landscape. Heterogeneity has been defined as "difference or diversity in kind from other things" as well as "composition from diverse elements or parts; multifarious composition" (The Compact Edition of the Oxford English Dictionary, 1979). A landscape which is considered to be heterogeneous is "diverse in character or composed of diverse elements " (The Concise Oxford Dictionary, 1976). For example, clearing woods for farmland will lead to increased heterogeneity at the landscape scale. A landscape previously comprised of forest becomes a more diverse, patchy mosaic of crop fields, built structures, fencerows and wooded islands (Merriam, 1988).

Forman and Godron's (1986) definition of landscape appears to best encapsulate existing definitions which utilize heterogeneity as their foundation. Landscapes are "heterogeneous and differ structurally in the distribution of species, energy and materials among the patches, corridors and matrix present. Consequently, landscapes differ functionally in the flows of species, energy and materials among these structural landscape elements". Heterogeneity may be examined both spatially and temporally within a landscape (Forman and Godron, 1986; Risser, 1987; Zonneveld, 1988).

Landscape Ecology

The field of landscape ecology can be traced back to the German biogeographer Carl Troll (Neef, 1982; Veen, 1982; Naveh and Lieberman, 1984; Forman and Godron, 1986; Rowe, 1988; Zonneveld, 1988 and 1990). In 1939, the concept 'Landschaft ecology' was introduced (Troll, 1971; Neef, 1982; Veen, 1982), born of two fields of study, geography and biology (Troll, 1971). One such area of study was A.G. Tansley's ecosystem concept, defined in 1935 (Troll, 1971; Zonneveld, 1988). Tansley (1935) proposed that "the whole complex of organisms present in an ecological unit may be called the biome" and that, "the fundamental concept appropriate to the biome considered together with all the effective inorganic factors of its environment is the ecosystem, which is a particular category among the physical systems that make up the universe. In an ecosystem, the organisms and the inorganic factors alike are components which are in relatively stable dynamic equilibrium" (Tansley, 1935). In addition, Troll promoted aerial photographs as tools to comprehensively view the ordering and distribution of landscape elements (Troll, 1971). As a result of the potential relationship between an ecological approach and aerial photography , two essential aims of Landschaft ecology arose:

1 . "the regional differentiation of the earth's surface, examining the spatial interplay of natural phenomena, a relatively "horizontal approach", and

2. "the functional interrelationships from a "vertical" view point, the interplay of phenomena at a given site (ecotope) studied as an ecological system".

Troll proposed that while the horizontal approach represented geographical Landschaft science, the vertical approach was specifically biological-ecological. Landschaft ecology was considered to embrace both senses, that is, "the study of an area according to its natural regional-ecological ordering and the major causal relationships at each site" (Troll, 1971). Landscape ecology was thus born of a "marriage" between the fields of geography and biology (Zonneveld, 1990).

In 1968, Troll revised the theory of Landschaft ecology as "the study of the main complex causal relationships expressed in a definite distribution pattern between the life communities and their environment in a given section of the Landschaft at various orders of magnitude" (Troll, 1968 as cited in Troll, 1971). A further refinement of this concept occurred in 1971 whereby landscape ecology was defined as "the study of the physico-biological relationships that govern the different spatial units of a region" (Troll, 1971; Forman and Godron, 1986). The influential relationship between geography and biology continues to be an integral component in the field of landscape ecology. Neither the sole study of the structural aspects (i.e geographically based) or the functional aspects (i.e. biologically based) of a heterogeneous landscape is considered sufficient for an adequate assessment of its respective patterns and processes. Rather, it has been acknowledged that the study of both these aspects in concert with a dynamic approach is necessary in order to obtain accurate information concerning any landscape (Zonneveld, 1990).

Terrestrial Fragmentation

Heterogeneous landscapes which have fragmented and isolated forest stands as a result of anthropogenic clearing have been well documented. One such heterogeneous landscape is that of Eastern and Southern Ontario. For example, forest islands having vegetation typical of the Great Lakes - St. Lawrence Forest Region (after Rowe, 1959) are proximal to the city of Ottawa and are surrounded by large expanses of fields and roads (Middleton and Merriam, 1983). Fragmentation effects such as loss of critical habitat, local population reductions or extinctions and altered gene flow have been observed for small woodland fauna (e.g. Wegner and Merriam, 1979; Middleton and Merriam,1983; Merriam, 1988; Merriam, 1990), birds (e.g. Wegner and Merriam, 1979) and flora (e.g. Middleton, 1982; Middleton and Merriam, 1983; Fritz and Merriam, 1993; Young, Merriam and Warwick, 1993; and Young and Merriam, 1994) within such islands.

The heterogeneous nature of the Deciduous Forest Region (after Rowe, 1959) within the urbanized area of southern Ontario also provides an opportunity to study forest fragmentation effects. Hounsell (1989) developed various methods of predicting avian habitat sensitivity to hydro transmission line disturbance. Baseline data on breeding birds and habitat characteristics of continuous forest are used to ascertain the effects of corridor fragmentation on the forest bird community (Sandilands, 1990).

Other studies which have addressed forest fragmentation in Southern Ontario have focused on the highly populated Niagara region. For example, Albanese (1987) examined the fragmentation effects of hydro right-of-ways on tree species within Short Hills Provincial Park. Willems (1988) investigated the presence or absence of biological continuity along portions of the Niagara Escarpment, peripheral to major urban settlements.

Theory of Island Biogeography

Many attempts have been made to understand the characteristics of fragmented forest islands in terms of the equilibrium theory of island biogeography. Delineated by MacArthur and Wilson in 1967 as an attempt to explain depleted faunal and floral populations within oceanic islands, its basic tenet is that the number of island species is a function of island size, age and the distance from a source of replacement species. It is proposed that "all other things being equal, large islands will support more species at equilibrium than smaller ones, islands closer to a mainland or other sources will harbour more species than more distant ones and islands with more environmental diversity will contain more species than those with relatively uniform biotopes. The number of species on an island therefore, is determined by a balance between immigration and extinction. Immigration varies with the distance to replacement sources and extinction varies with island size. Theoretically, at equilibrium each new immigrant species will be matched by a species extinction" (MacArthur and Wilson, 1967).

The application of this theory to terrestrial systems is common. However, it is proposed that forest patches (notably within farmland matrices) differ from true oceanic islands (Burgess, 1988). Agricultural matrices may be considered different barriers than oceans. Small mammals may cross such matrices relatively easily, as well, weed seeds and other plant types will readily germinate. A finite percentage of propagules is considered to disperse between terrestrial islands as distances between forest patches are often less than the distances between oceanic islands (Burgess, 1988). In addition, due to their smaller areas terrestrial fragments are considered to be more environmentally homogeneous than ecosystems on oceanic islands (Burgess, 1988). While the theory of island biogeography may hold some attraction in studies of forest fragmentation, Middleton and Merriam (1983), noted no effects of insularity on various plant, mammal and invertebrate species existing within forest islands in an agricultural matrix. It was concluded that "the farmland did not operate as a system of biogeographic islands because woodland species had

evolved efficient mechanisms for medium-distance movement in response to the ubiquitous spatial heterogeneity of intact forests prior to fragmentation" (Middleton and Merriam, 1983).

Terrestrial Fragmentation Impacts: Edge Effects

Anthropogenically-induced landscape fragmentation creates relatively small, and sometimes, irregularly shaped vegetative islands. An increase and spread of ecotonal (or edge) habitats, and a decrease in interior habitat throughout forest islands, have also been observed (Figure 1) (e.g. Elfstrom, 1976; Levenson, 1981; Ranney, Bruner and Levenson, 1981; Forman, 1982; Harris, 1984; Forman and Godron, 1986; Laurance and Yensen, 1991; Merriam and Wegner, 1992). Edge habitats have greater biomass per unit area than their interior counterparts, and are considered more vegetatively dense and biologically productive (Forman and Godron, 1986). Forest edges are therefore considered to be heavily utilized by various species of wildlife (Odum, 1959).

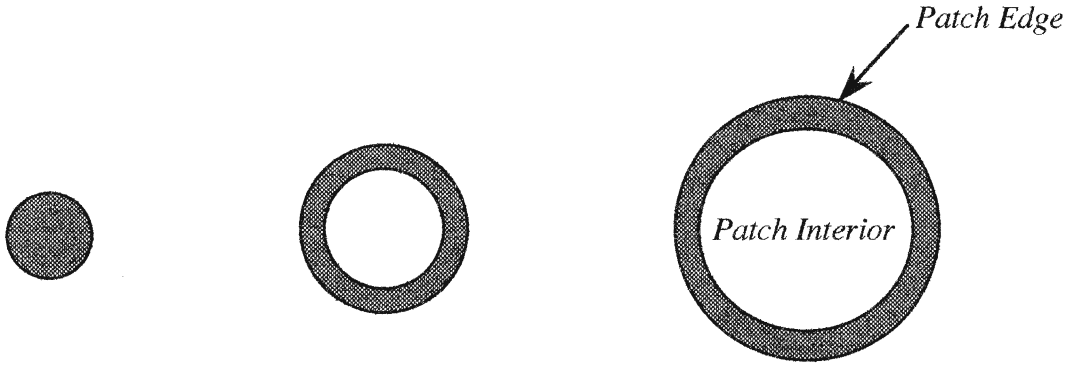
Terrestrial fragmentation reduces and subdivides forest island floral and faunal populations. Therefore, these populations are increasingly exposed to ecological changes associated with increased edge habitat (Wilcove, McLellan, and Dobson, 1986). The effects of edge-induced ecological changes within fragmented forests are considered to be varied in number (Laurance and Yensen, 1991). Therefore, it is here that much of the research concerning landscape fragmentation is found.

Various effects of increased areas of edge within forest patches have often fallen within the area of avian research (Hounsell, 1989). The majority of avian research has been devoted to minimum territory size requirements for interior species (Hounsell, 1989) and interspecific competition between interior and generalist avian species (e.g. Whitcomb, 1977; Whitcomb, Robbins, Lynch, Whitcomb, Klimkiewicz and Bystrak, 1981; Hounsell, 1989).

Less research has been conducted on the effects of forest fragmentation on other animals. Observations of white-footed mouse (*Peromyscus leucopus*) and chipmunk (*Tamias striatus*) populations within forest fragments in Eastern Ontario have indicated that

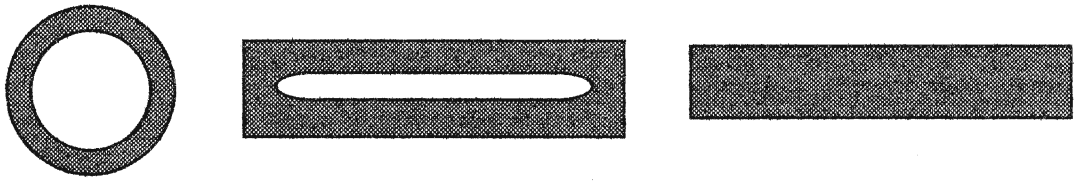
Fig. 1. Decreases in size and increases in shape irregularity of patches leading to decreases in interior habitat and increases in edge habitat.
(after Forman and Godron, 1986).

Size



Small Intermediate Large

Shape



Isodiametric Elongated Narrow elongated

they become periodically small, hence local extinctions occur (e.g. Merriam, 1990; Merriam and Wegner, 1992).

Tree species have different abilities to withstand reduced sunlight conditions. The term tolerance was introduced by Zon and Graves (1911 as cited in Baker, 1949) in order to aid in the assessment of a particular species affinity for shaded habitats. Such affinities have been subsequently revised (Baker, 1949). Edge and interior tree communities within wooded islands have been found to be different based on the shade-tolerance (or shade-intolerance) of their constituent trees. Studies of fragmentation effects on vegetation have proposed that the majority of vegetation types which occur along forest island margins are shade-intolerant (Ranney et al., 1981; Levenson, 1981). Forest island edge habitats therefore provide refuges for shade-intolerant species such as *Quercus rubra* L. (red oak) (Brothers, 1993). Subsequently, the decline of forest interior plants (i.e shade-tolerant) also occurs within such habitats (Gysel, 1951; Ranney et al., 1981; Levenson, 1981).

Studies of forest fragmentation effects on genetic diversity and structure of plant communities have occurred relatively recently (e.g. Foré, Hickey, Vankat, Guttman and Schaefer, 1992; Young, Merriam and Warwick, 1993; Young and Merriam, 1994). Foré et al. (1992) observed that "the high potential for long-distance gene flow of *Acer saccharum* Marsh. (sugar maple) was enhanced by altered wind flux across fragmented landscapes". It was subsequently concluded that "forest fragmentation did not always result in a greater isolation of local populations of this species" (Foré et al., 1992). In support of such a conclusion, Young et al. (1993) also observed that "the genetic variation of *A. saccharum* was maintained within isolated patch populations". However, it was acknowledged that such a result may have been due to a limited number of generations since the onset of fragmentation. Young and Merriam (1994) suggest that "forest fragmentation has in fact affected the genetic structure of this species by altering patterns of gene flow within, and possibly among, forest patch populations".

The fragmentation of the earth's surface has contributed to the heterogeneity of many landscapes. The potential effects of such heterogeneity upon relatively homogeneous ecosystems gain increasing importance. The study of the relationships among homogeneous ecosystems promotes an understanding of the functioning of the landscape as a system. Such studies form the basis for the field of landscape ecology.

An ideal landscape in which the effects of disturbance may be determined is a farmland matrix in which remnant forest islands exist. Of particular interest in this thesis are the effects of edge (i.e spatial and temporal) upon tree and sapling populations within forest islands of Short Hills Provincial Park. Located within the Region of Niagara, this farmland landscape area is spatially heterogeneous due to severe human disturbance and forest fragmentation. Any observed edge effects may suggest the importance of human-induced heterogeneity upon relatively homogeneous ecosystems. Results of this thesis may be used as the basis for some management recommendations for the park. While the exact nature of this thesis appears to have no counterpart in relevant literature, any determination of edge effects may be best compared with the prior studies of Ranney (1978); Ranney et al. (1981) and Levenson (1981).

STUDY AREA

This study was conducted from May to October, 1992, in Short Hills Provincial Park, located southwest of St. Catharines, Ontario (Figure 2). Its current 688 hectare area represents the culmination of a twenty year land acquisition endeavor by the Ontario government as part of an effort to protect the natural features of the Niagara Escarpment and to provide recreation associated with such an area (Ontario Ministry of Natural Resources, 1990). Recommendations of a Short Hills Provincial Park Advisory Committee appointed in 1974 by the Minister of Natural Resources emphasized recreational opportunities which required a minimum level of development. Such recommendations provided direction for the master plan for Short Hills which was completed in 1977. Subsequently, the area became regulated as a "natural environment" provincial park under the Provincial Parks Act (Regulation 45/85) in 1985 (OMNR, 1990), in order to reflect "the provincially and regionally significant natural features present and the high quality recreational opportunities it provides" (OMNR, 1990). The mandate of natural environment provincial parks is "the preservation of outstanding aesthetic, natural and historical features for the purposes of recreation and education" (OMNR, 1977).

Approximately every ten years, park management plans are reviewed and updated. Thirteen years following the implementation of the 1977 Short Hills Park management plan, such a review was undertaken by the Ontario Ministry of Natural Resources. The general orientation of the original plan towards trail use with limited development was accepted as the guiding influence for the revised planning process for Short Hills (OMNR, 1990). The hilly countryside of both forests and open spaces of the park is considered one of the few areas between the cities of Hamilton and Niagara Falls which offers residents of the Niagara region a relatively large natural environment for passive recreational opportunities (Ontario Ministry of Natural Resources, 1977).

Numerous bedrock exposures may be found within the park. "This bedrock, represented by various limestone, dolomite, shale and sandstone formations, is the result of

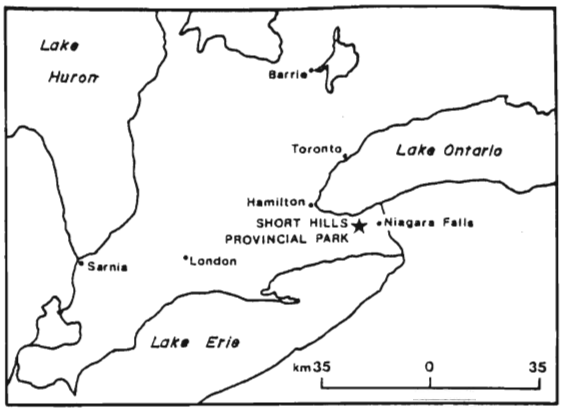
Fig. 2. Geographical location of Short Hills Provincial Park within the Niagara Region, south of St. Catharines, Ontario. (after Ontario Ministry of Natural Resources, 1990).

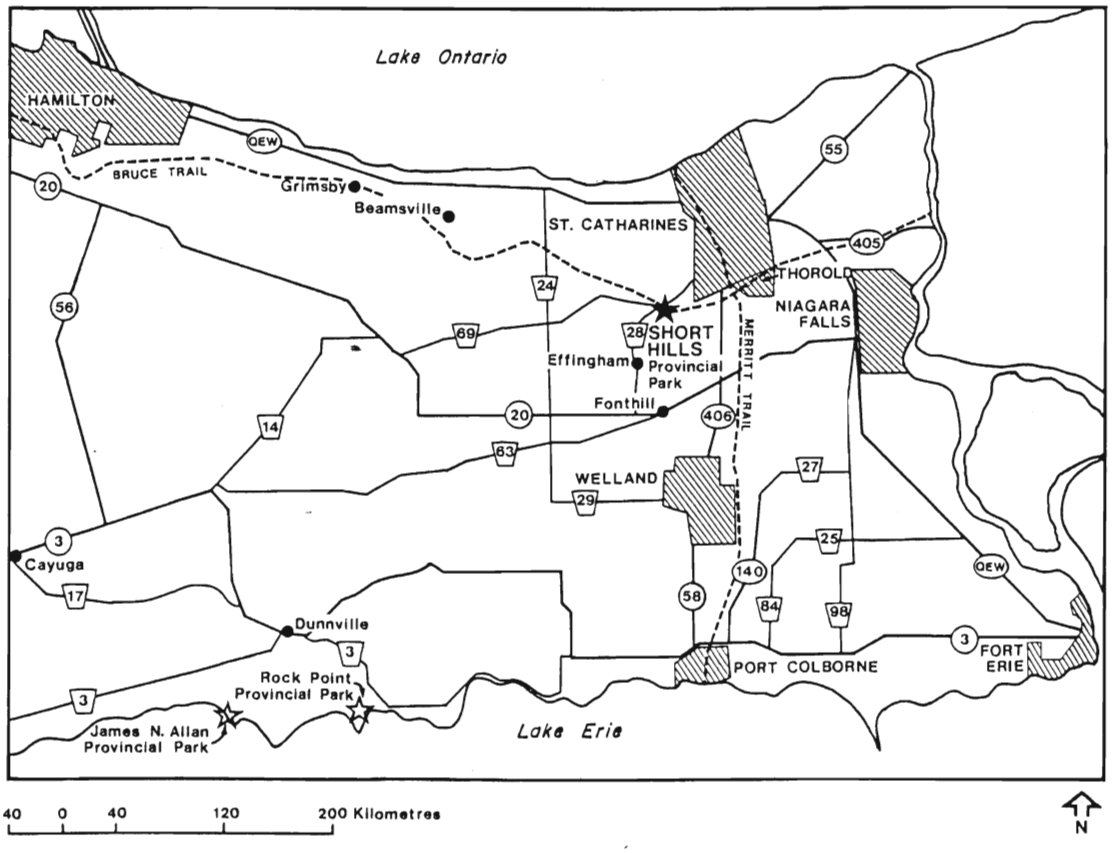
REGIONAL CONTEXT

★ Short Hills Provincial Park

☆ Provincial Park

Urban Area





sedimentation within a warm, shallow sea which occupied this area approximately 440-425 million years ago. The surface expression of the bedrock in the park is dominated by the Niagara Escarpment whose steep rock face has been formed by the differential erosion of a hard cap rock and a softer underlying rock "(OMNR, 1977). The majority of the park is set within a reentrant valley cut into the escarpment by the erosional processes of several ancient rivers (OMNR, 1977). It is now postulated that Lakes Ontario and Erie were once connected by a reentrant valley, which contributed to the undulating landscape of the area (OMNR, 1977). The present Twelve Mile Creek in turn dissected this valley to form the "Short Hills" (OMNR, 1990).

The diverse biological significance of Short Hills Park encompasses both aquatic and terrestrial environments. It is known to have the only spring-fed streams within the Niagara Peninsula. Such streams form the headwaters of Twelve Mile Creek (OMNR, 1977 and 1990), the last provincially significant coldwater stream in Niagara (Preservation of Agricultural Lands Society, 1988). This stream is recognized as the sole habitat of *Salvelinus fontinalis* (brook trout) within the park (OMNR, 1977 and 1990).

Short Hills Park lies within the Deciduous Forest Region, an area which occurs in southwestern Ontario between Lakes Huron, Erie and Ontario (Rowe, 1959). Eastern hardwood tree species such as *A. saccharum* and *Fagus grandifolia* Ehrh. (american beech) which are also common to the Great Lakes - St. Lawrence Forest Region to the north, dominate this region (Rowe, 1959). In addition, southern hardwood species such as *Liriodendron tulipifera* L.(tulip tree) and *Sassafras albidum* (Nutt.) Nees (syn. S. variifolium (Salisb.) Ktze.) (sassafras) have their northern limits within this locality (Rowe, 1959). The vegetation association of *A. saccharum* and *F. grandifolia* is generally located on upland and hilltop areas of the park. Normally associated with deep, fertile, well-drained, and moist soils (Hosie, 1975; OMNR, 1977), this association is the most common of the park (OMNR, 1977 and 1990). Other common tree associations within the park include those normally situated on southern slopes such as *Q. rubra* and *Carya ovata*

(Mill.) K. Koch (shagbark hickory), those normally situated on northern slopes such as *Tsuga canadensis* (L.) Carr. (eastern hemlock) and *Pinus strobus* L. (white pine) as well as those commonly found in valleys, such as *Ulmus americana* L. (white elm) and *Fraxinus americana* L. (white ash) (OMNR, 1977). Southern hardwood species such as *L. tulipifera* are found scattered throughout the park (Albanese, 1987; OMNR, 1990).

In addition to the varied topography, the diversity of historic land uses gives rise to the park's complex mosaic of plant communities. Inhabitants of the park area prior to the arrival of the first white fur traders in the 17th century, were the nomadic, Neutral Indians (Brehaut, 1968). These tribes practised primitive agriculture; visible effects of such activity consisted of scattered patches of grassland within forests. Once an area lost its productivity, it was allowed to regenerate and more viable areas were subsequently utilized (Watson, 1945 as cited in Brehaut, 1968).

The Short Hills area was one of the first three sites above the Niagara Escarpment to be pioneered by peoples of European culture (Watson, 1945 as cited in Brehaut, 1968). The initial settlers were United Empire Loyalists from the United States, who having been defeated in the Revolutionary War, settled in the closest British colony. The presence of the headwaters of the Twelve-Mile Creek proved to be both a power source for milling and an irrigation source for agriculture in the late 1780's. As well, the light, loamy, well-drained soils of this area were considered to be ideal for mixed and fruit farming as well as market gardening. While the major agricultural crop during the initial settlement period was corn, it has been noted that wheat crops gained increasing prominence in the beginning of the 1800's. Large areas of forest were subsequently removed in order to create extensive wheat fields (Brehaut, 1968).

The production of agricultural crops such as hay and fruit continue today. There has also been an increase in the amount of urban, residential, recreational and industrial usage within the Short Hills area (Brehaut, 1968). Comparisons of aerial photos dating

back to 1934 with those of 1991 indicate that the nature and extent of anthropogenic activities surrounding the park has remained relatively constant in the last 60 years.

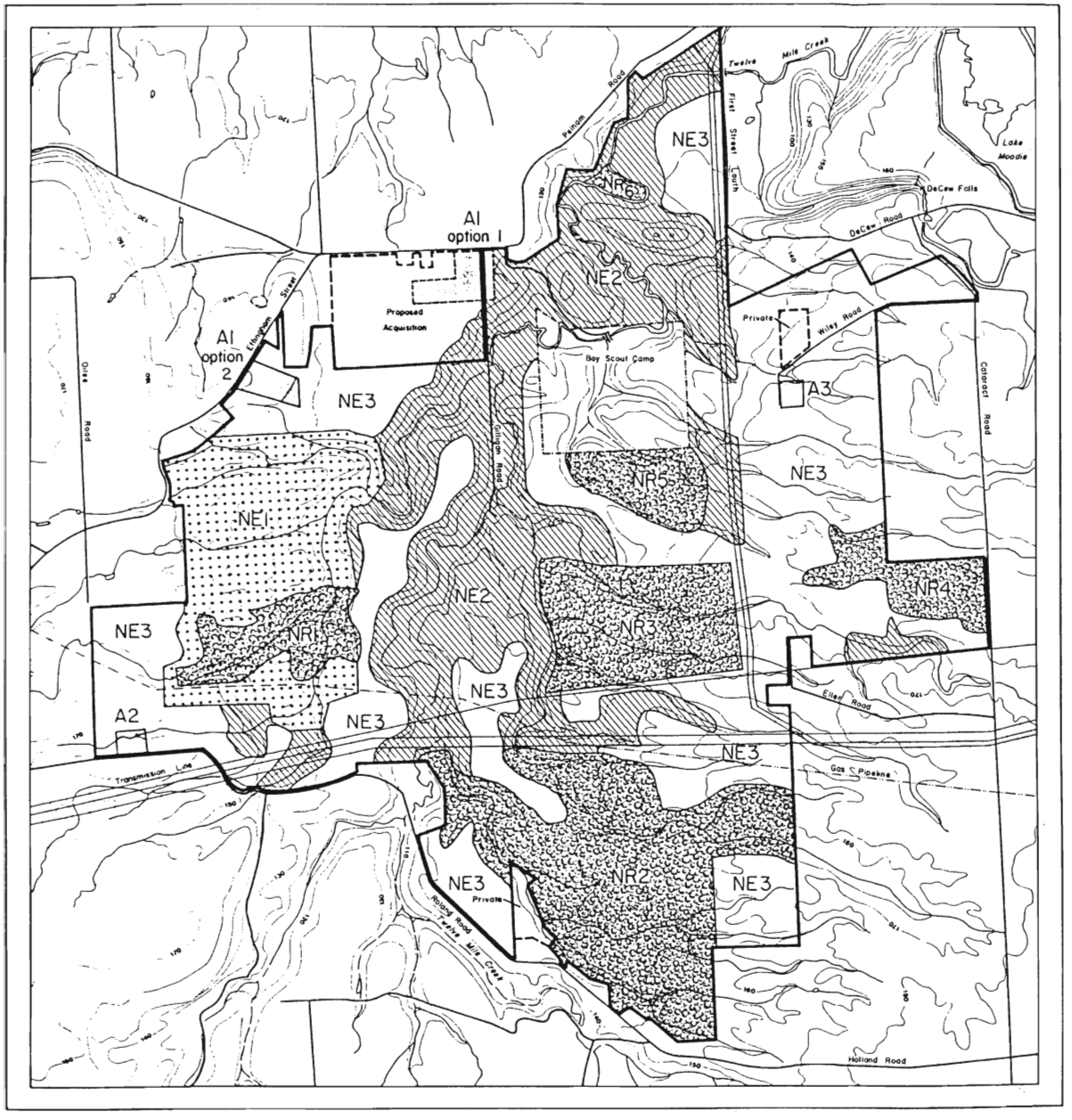
The most dominant human features within the boundaries of Short Hills Park are utility corridors. A 2.6 km hydro right-of-way runs in an east-west direction throughout the entire length of the park. Initially constructed in 1915 with subsequent stages constructed in 1929 and 1949 and running through some of the oldest and least disturbed woods, this 100-150 metre wide strip continues to be cleared periodically by Ontario Hydro (Albanese, 1987). An additional hydro corridor was cleared and installed in the fall of 1943 (P. Beed, pers. comm., Ontario Hydro Representative, Dundas) and runs north-south through the park. A 20 inch deep, gas pipeline right of way also runs in an east-west direction throughout the park. Originally cleared in 1954, it was recleared and subsequently deepened by 10 inches in 1988 (K. Spriggs, pers. comm., Trans Canada Pipeline Representative, Ancaster).

At the present time, forest covers approximately half of the park's area. The remaining 50% of the park is represented by old field areas (30%), actively cultivated farmland (15%) and *Pinus resinosa* Ait. (red pine), *P. strobus*, and *Piceaglauca* (Moench) Voss. (white spruce) plantations (5%) (OMNR, 1990).

Sample areas utilized in this study are those proposed as Nature Reserve Zones (designated as NR) within the recently proposed Short Hills Park Preliminary Management Plan (1990). Such zones are considered to "represent areas of the greatest environmental sensitivity within the park and thus requiring the greatest amount of protection" (OMNR, 1990). The general policy advocated for each of these areas within the Preliminary Management Plan is the "protection of significant natural features for purposes such as providing opportunities for non-destructive scientific research and compatible recreation" (OMNR, 1990).

Four of six proposed Nature Reserve Zones were sampled (Figure 3). NR1 (also known as Dry Falls Valley - Figure 4) is a 20-ha site noted for its possession of Dry Falls,

Fig. 3. Location of Nature Reserve Zones within the preliminary management plan of Short Hills Provincial Park (after Ontario Ministry of Natural Resources, 1990).



SHORT HILLS PROVINCIAL PARK

PROPOSED ZONING

metres 100 0 100 300 500 700 metres

- Provincial Park Boundary
- Stream, Intermittent Stream
- 160 Contour (interval 10 metres)
- Private, Proposed Acquisition

Access Zones

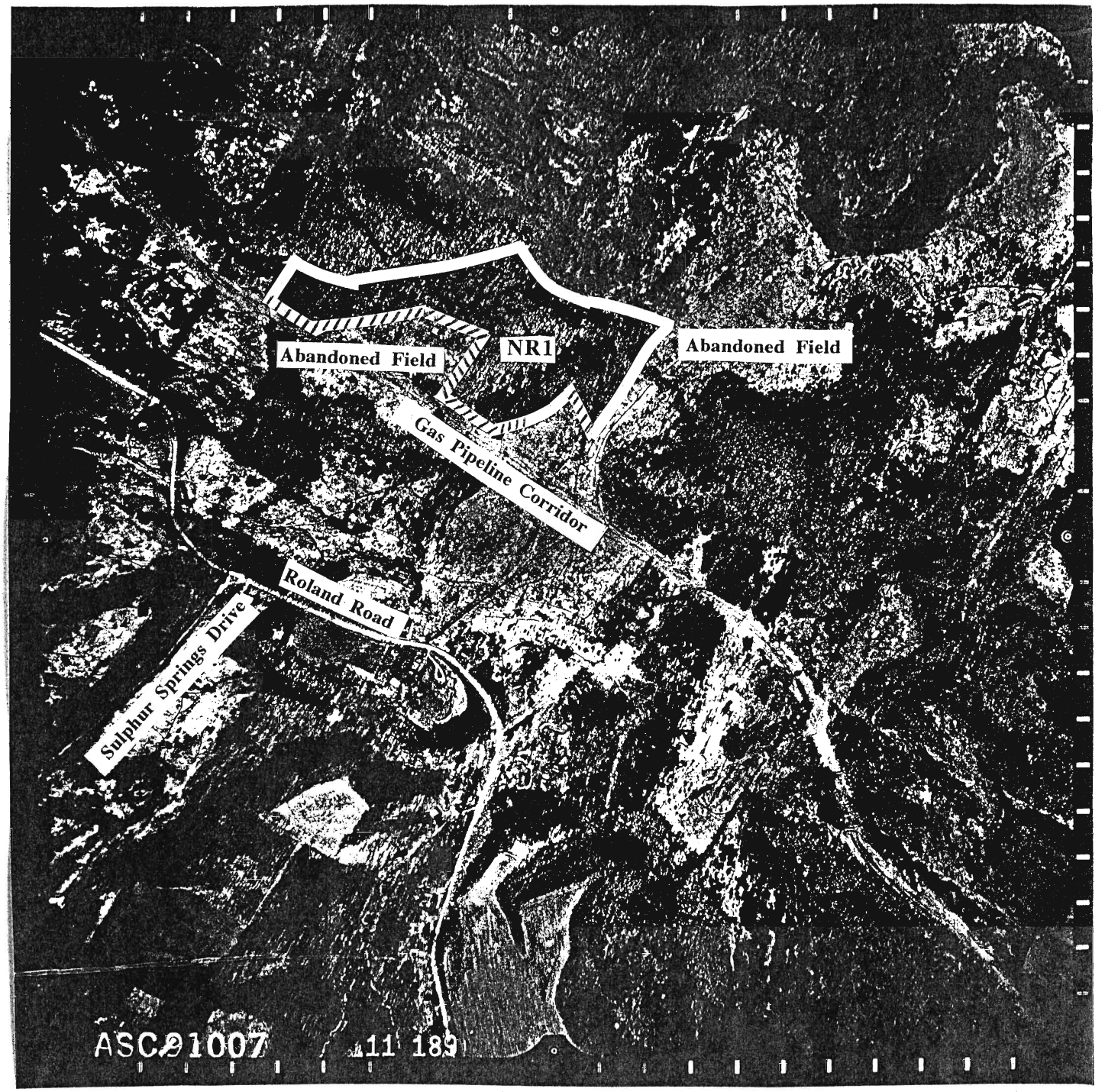
Nature Reserve Zones

Natural Environment Zones:

- NE1 Reentrant Valley-West Side
- NE2 Valleylands and Forests
- NE3 Tablelands and Fields

Fig. 4. Aerial photo indicating the boundary of NR1 (Dry Falls and Area) and surrounding land uses.

Note: the hashed border indicates the sampled edge

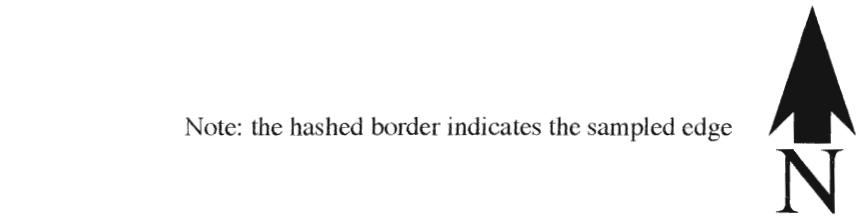


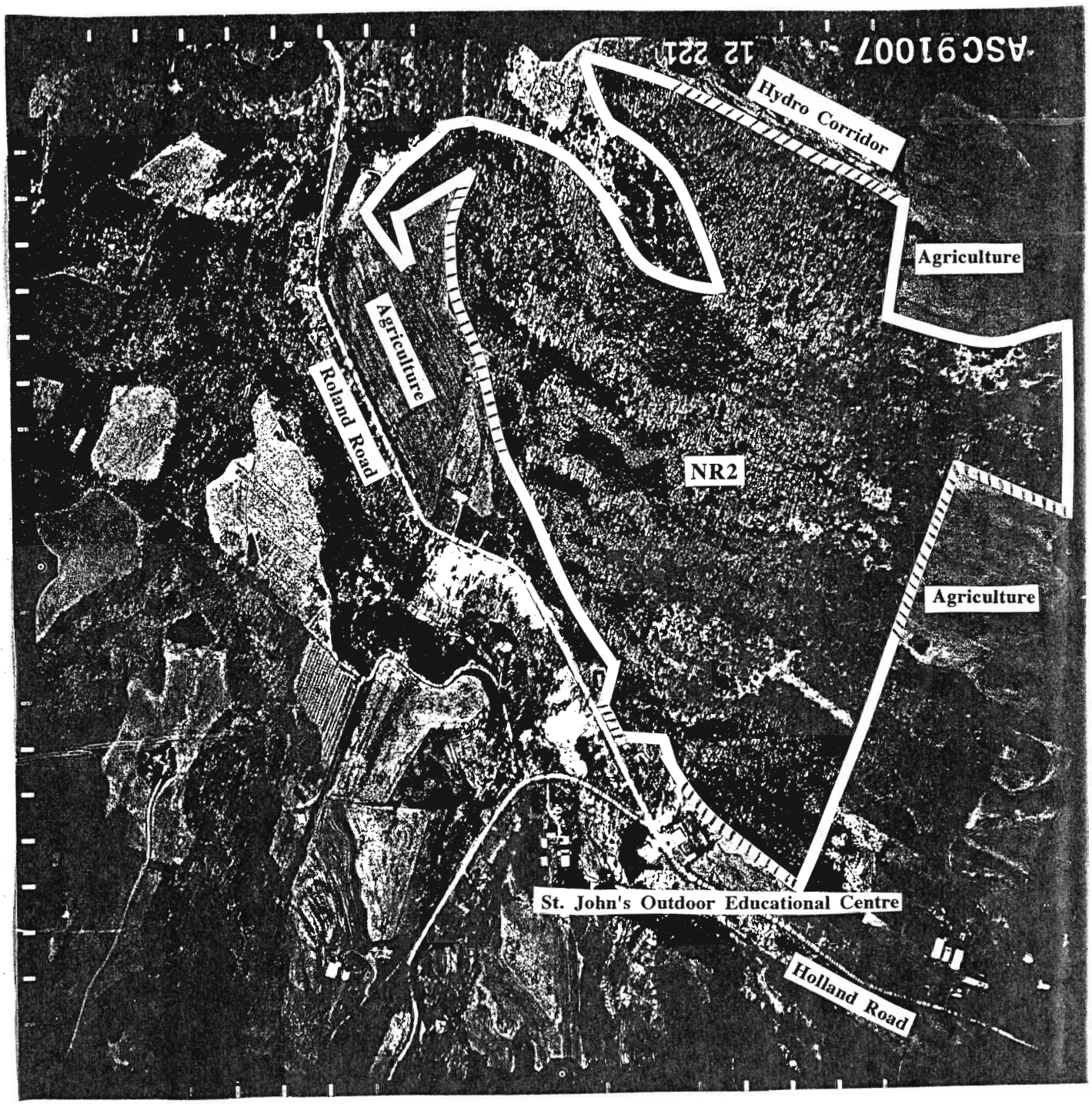
a major feature of the park (OMNR, 1990). As this valley is notably representative of earth science features of the pre-glacial reentrant valley, it has been designated as a provincially significant Area of Natural and Scientific Interest (ANSI) by the Ontario Ministry of Natural Resources (Gould, 1989; OMNR, 1990). Human disturbances within and proximal to this area include extensive trail systems (Gould, 1989), old field sites, as well as visible hydro and gas pipeline right-of-ways extending primarily along its southern border (OMNR, 1990).

NR2 (also known as Samuel Chandler's Valley - Figure 5) is a 90-ha dendritic valley site representative of much of the diverse vegetation of the park. The vegetative association of *A. saccharum-F. grandifolia* is commonly observed within this area along with abandoned fields and planted conifer plantations. However, the unique nature of NR2 is best reflected by its possession of provincially significant tree and plant species such as *L. tulipifera* and *Aster divaricatus* L. (white wood aster). A particularly environmentally sensitive area of the park termed the "hemlock valley" is also located within this area (OMNR, 1990). NR2 has also been designated as an ANSI to preserve such representative vegetation of the Twelve Mile Creek Valley System (Gould, 1989). However, human disturbances surrounding this area are numerous and diverse. Agricultural activities continue to occur along its borders; as well, hydro and gas pipeline right-of-ways extend along its northern perimeter (OMNR, 1990).

Fig. 5. Aerial photo indicating the boundary of NR2 (Samuel Chandlers Valley) and surrounding land uses.

Note: the hashed border indicates the sampled edge





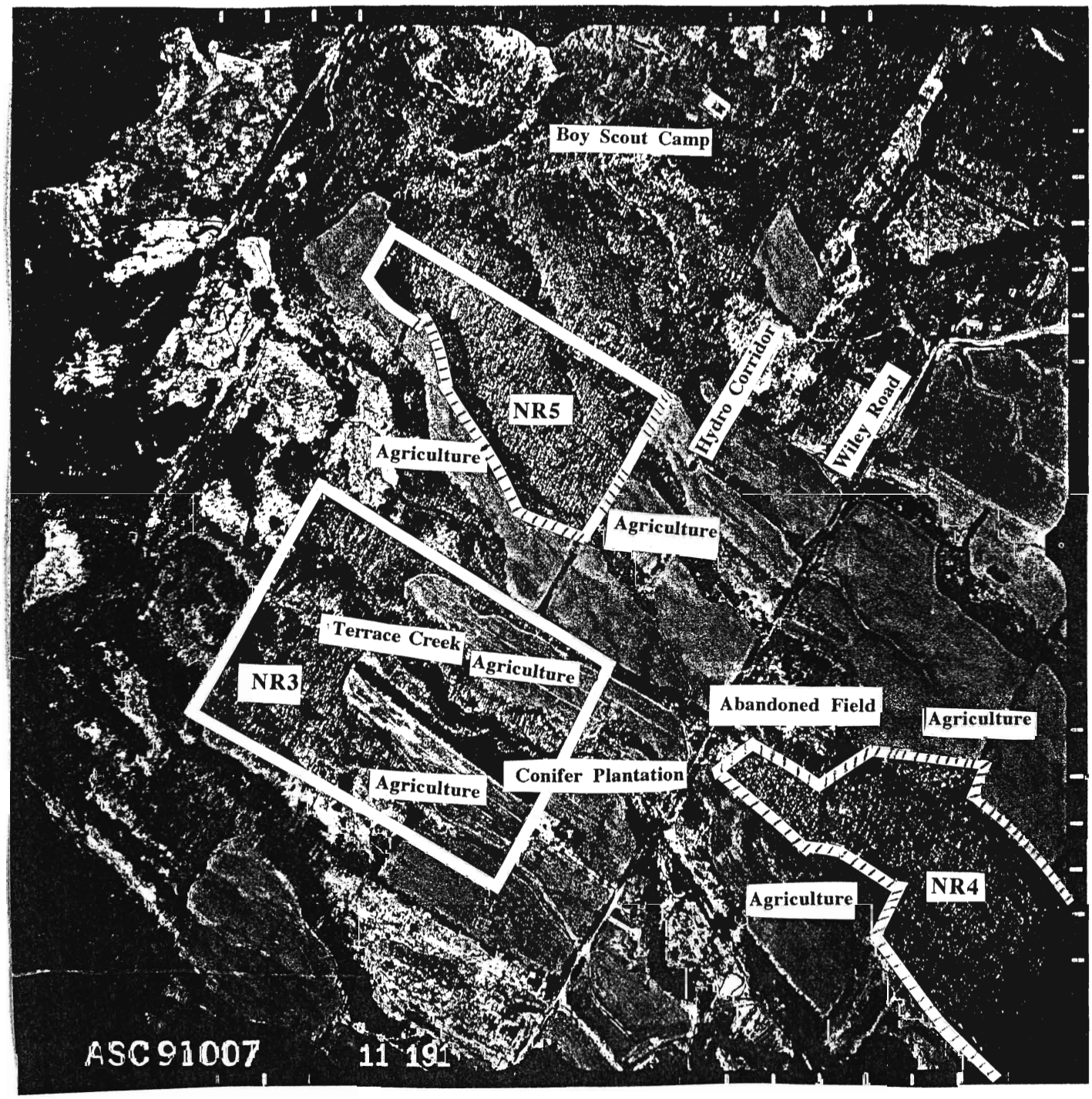
NR4 (also known as Cataract Woods - Figure 6) is an 18-ha site bordered largely by presently utilized agricultural fields, and is comprised of relatively mature woods with a fairly large Carolinian component in the floral community (OMNR, 1990). Sensitive soils and steep slopes, as well as provincially rare flora such as *Aster divaricatus* and *Liriodendron tulipifera* , contribute to the area's overall sensitivity (OMNR, 1990). While this area is also a significant habitat for *Dryocopus pileatus* (pileated woodpecker), significant disturbances such as snowmobiles, horses and motorcycle usage continue to pose serious threats to the integrity of these woods (OMNR, 1990).

NR5 (also known as Wetaskiwin Woods - Figure 6) is a 15-ha site composed of "mature woods graced by two winding creeks which tumble over several waterfalls" (OMNR, 1990). Although considered to be "remarkably well preserved", the extensive informal trail system within this area has shown signs of deterioration and over-use. As the boundary between the area and the nearby Boy Scout Camp (Camp Wetaskiwin) is not well-marked, the Ministry of Natural Resources has observed inappropriate usage of park land (e.g., the construction of structures such as tree houses) (OMNR, 1990). Evident human disturbances such as active agriculture and hydro corridors are found on its outer perimeter (OMNR, 1990).

NR3 (also known as Terrace Creek - Figure 3) is depicted within the Short Hills Preliminary Master Plan as a relatively large area of 40 ha (OMNR, 1990). However, examinations of aerial photographs (Figure 6) indicate that the portrayal of this area as a relatively continuous forest is misleading. Large sections of NR3 are currently under cultivation. Potential edge areas represent an extremely small sample area of perhaps 100 m in total. As well, a large portion of the vegetation of NR3 does not reflect the typical vegetation of Short Hills; a large pine plantation currently exists along the southern boundary of Terrace Creek. Due to such factors, NR3 was considered unsuitable, and as such was not sampled.

Fig. 6. Aerial photo indicating the boundaries of NR3 (Terrace Creek), NR4 (Cataract Woods) and NR5 (Wetaskawin Woods) and surrounding land uses.

Note: the hashed border indicates the sampled edge



METHODS

The purpose of this thesis is to ascertain whether or not the woody vegetation of several forest islands (i.e. NR1, NR2, NR4, NR5) within Short Hills Provincial Park are responding in some manner to environmental conditions created by edge areas (e.g. they are experiencing an edge effect). The specific types of edge effects studied were spatial (e.g. the woody vegetation of the island interiors have different sizes, densities and distributions than the vegetation closer to the edges of the islands) and temporal (e.g. a particular vegetative species or group of species within the islands have become more important over time with respect to other species as a result of increased edge).

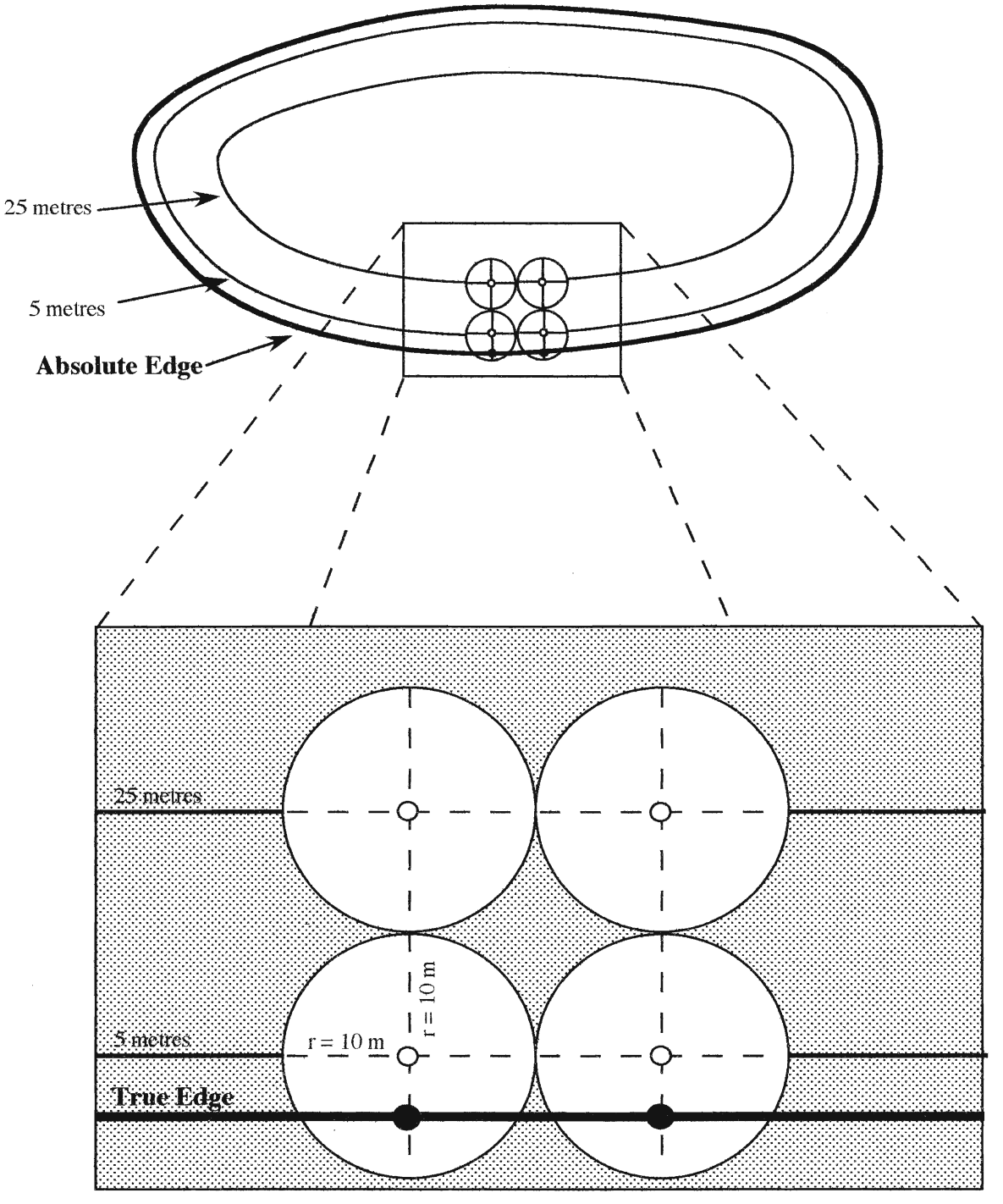
Areas of absolute edge within each sample area (i.e. NR1, NR2, NR4, NR5) were the subject of the sampling program. For the purposes of this thesis, the outer-most mature trees of an absolute edge had to have minimum diameter at breast height measurements (dbh) of $\geq$ 10 cm (see below for more detailed explanation of size and age criteria). An absolute edge must also have been characterized by a closed canopy of woody species and had to contain a floor layer of leaf litter (as opposed to grass or field plants).

In order to ensure independent samples of young and mature vegetation and thus to avoid an age continuum, two distinct age/size criteria were used. Saplings (younger vegetation) were defined as woody vegetation having dbh measurements of 2-4 cm. Trees (mature vegetation) were defined as woody vegetation having dbh measurements of $\geq$ 10 cm. Sapling and tree designations which were used in several previous studies on edge effects are similar to those used in this thesis. For example, Ranney (1978) and Ranney et al. (1981) defined saplings as "having measurements of 2.5-10.0 cm dbh and trees as having dbh measurements of > 10.0 cm". Brothers (1993) defined saplings as "having dbh measurements of 2.5-9.9 cm dbh and trees as individuals having dbh measurements if $\geq$ 10.0 cm". Gysel (1951) defined trees as "stems having dbh measurements of $\geq$ 12.0 cm".

The dbh measurements of trees and saplings in each of the four sample areas, was one of the foundations by which both spatial and temporal edge effects were gauged. These measurements were taken at points located on two sample rings at different distances in from the absolute edges sampled: the exterior ring was located 5 m in from the absolute edges sampled and the interior ring was an additional 20 m into each area (or 25 m in from the absolute edges sampled) (Figure 7). The most peripheral sampling distance of 5 m was designed to eliminate small scale minor differences which may have occurred at the outermost boundaries and the 25 m distance represents a figure which is consistent with other edge distance scales used by other researchers (e.g. Gysel, 1951; Ranney et al., 1981). In addition, area measurements of the four proposed nature reserve zones in question indicated that the distance of 25 m would allow a significant sample size. If the absolute edge was located at a distance greater than 10 m from peripheral outlying vegetation, the area was bypassed in order to avoid sampling those areas which were comprised mainly of herbaceous vegetation.

The parameters of relative density (equation#1), relative frequency (equation #3), and relative dominance (equation #4) were calculated for the purposes of ascertaining importance values (equation #5). The importance values were used in addition to dbh measurements for the purpose of determining spatial and temporal edge effects. As a systematic measure, importance values have often been used to calculate the position or "importance" of a particular species, relative to that of associated species within a forest ecosystem (Smith, 1986). The sensitivity of the importance value to such variables as apparent contagion or exceptional basal area is also considered to be of significance (Curtis and McIntosh, 1951). Importance values have been and continue to be, commonly utilized in the vegetative analysis of a wide variety of forested areas (e.g. for just a few examples see Curtis and McIntosh, 1950 and 1951; Levenson, 1980 and 1981; Ranney, 1978; Ranney et al., 1981). Importance values could not always be calculated for all tree species

Fig. 7 Hypothetical forest patch illustrating the two sampling rings located at 5 and 25 metres in from the true edge. Hypothetical sample points with 10 metre radii show no overlap, indicating independence of all sample points.


25 metres
5 metres
Absolute Edge
25 metres
5 metres
True Edge
r = 10 m
r = 10 m

and sapling species sampled at 5 and 25 m within the park (Appendix 2 and 3). Relative density, relative dominance and relative frequency could be calculated for a particular tree species or sapling species at either 5 or 25 m in some or all of the four sample areas. However, the calculation of importance values required that a particular species occur at both 5 and 25 m and in all four sample areas.

Relative Density (R.Den.):

$$\textbf{R.Den.} = \frac{\text{number of trees or saplings of species } i}{\text{total number of trees or saplings of all species}} \times 100 \qquad (1)$$

Relative Frequency (R.Freq.):

$$\text{Frequency of species } i = \frac{\text{points of occurrence for species } i}{\text{total number of points sampled}} \qquad (2)$$

$$\textbf{R.Freq.} = \frac{\text{frequency of species } i}{\text{sum of frequencies of all species}} \times 100 \qquad (3)$$

3. ***Relative Dominance:***

a) basal area for species *i* (in m^2) is obtained by extracting the basal area for each individual tree or sapling (in reference to its diameter at breast height measurement (cm) from a basal area table. Individual basal areas for species *i* are summed, the obtained figure represents the basal area for that species.

$$\textbf{R.Dom.} = \frac{\text{basal area for species } i}{\text{sum of basal areas for all species}} \times 100 \qquad (4)$$

4. ***Importance Value:***

$$\textbf{I.V.} = \textbf{R.Den.} + \textbf{R.Freq.} + \textbf{R.Dom.} \qquad (5)$$

(after Cottam and Curtis, 1956; Brewer and McCann, 1982)

Using the mechanisms and criteria as described above, two null hypotheses were formulated in order to determine specifically if the fragmented wooded areas of Short Hills Provincial Park were experiencing spatial and temporal edge effects:

i. there is no significant difference between measurements taken at 5 and 25 m as determined by statistical analyses.

ii. there is no significant difference between the measurements of trees and saplings as determined by qualitative analyses.

The sampling method utilized for this research project was the point-centred quarter method (after Cottam and Curtis, 1956), a method which uses distance-measurements as opposed to fixed area measurements, such as those used in the more typical quadrat sampling method. While the mechanics of distance-measurement techniques vary, the principle upon which they are all based is similar. "In a stand of any plant community, the individuals exist in a certain number, distributed over a certain area; this characteristic is normally referred to as density. In fixed-area plot sampling (such as quadrats), a relatively small portion of the total area is sampled, usually by means of a number of separate subsamples. In each of these subsamples, the density is determined directly by counting and the result is subsequently expanded to total density per stand (or by ha), using the ratio between sample size and stand size" (Cottam and Curtis, 1956).

As an alternative to the quadrat-sampling method's utilization of the number of plants per unit area, the amount of area per plant (**M**) or mean area (the reciprocal of density) is the concept on which distance measurement sampling is based. "When plant abundance is offered as mean area (**M**), the use of distance measurements between plants allows the measurement of the abundance of those plants, as $\sqrt{\mathbf{M}}$ is a direct indication of the spacing of plants. Therefore, a measurement of the actual spacing in the field can lead

to an accurate estimate of the mean area and the density of the particular area of study" (Cottam and Curtis, 1956).

Each sample point on the 5 m (N = 592) and 25 m (N = 556) sample rings was derived using random numbers between 0-1, subsequently used in the formula 20 m + the random # (0-1) X 20 m. Therefore, the minimum distance between points was 20 m, the average was 30 m and the maximum was 40 m. An initial survey of the park was performed in order to ascertain whether the mean distance from any sampling point to the nearest tree or sapling would be less than 10 m. Results of the survey indicated this to be true. The use of 20 m as a minimum distance between points as well as the distance separating the two sampling rings was derived from the survey results. This distance was sufficient to avoid sampling any tree twice and to ensure that the samples were statistically independent from each other (Figure 7).

Two separate size criteria for each sample area were utilized for this study. A minimum of 20 points per sample ring was proposed in order to obtain an adequate minimum sample size for the random sampling scheme. In addition, it was necessary that the 5 and 25 m sample rings of each wooded area have a perimeter of a minimum of 600 m (i.e minimum of 20 points X 30 m average distance between points). Therefore, if each sample site was treated as circular, the diameter of each wooded area had to be a minimum of approximately 200 m (i.e. 600 m $\div \pi$).

The latter size requirement is similar to the criterion used by Hounsell (1989) who proposed that "the distance between two opposing edges be a minimum of 200 m, as a high forest edge to area ratio was found to occur when the edge to edge distance of forest islands was less than 200 m".

Aerial photos (1991) of Short Hills Park from the Map Library of Brock University were used during the field analysis to precisely locate the sample area boundaries. As well, they were used in conjunction with a Compensating Polar Planimeter

(Keuffel & Esser Co., model # 620015) in order to confirm the area (ha) of each sample site as given by the Ontario Ministry of Natural Resources (1990).

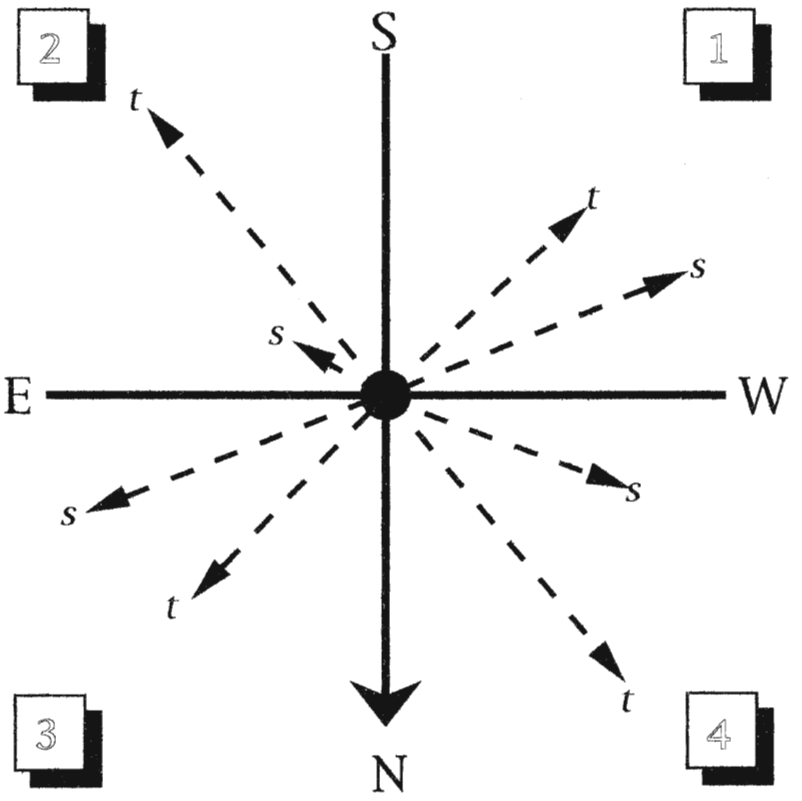
Each sample point was divided into four quadrants based on cardinal directions (Figure 8). Within each quadrant, two point-to-plant distances in m were obtained (i.e. one for trees, one for saplings) by using a 50 m measuring tape. Hence, a total of eight distance measurements were obtained per point. Tree and sapling dbh measurements were obtained using wooden tree calipers supplied by the local Fonthill office of the Ontario Ministry of Natural Resources, and the species of each was recorded. If an unfamiliar tree or sapling species was sampled, leaf samples were pressed and identified (using a key for tree species within Hosie, 1975) at a later date. Leaf samples of all trees or saplings sampled are preserved on herbarium sheets in the Department of Biological Sciences, Brock University in order to offer corroboration of correct identification.

In addition to the main sampling program conducted from May-October, 1992, a variance sampling regime was also conducted once a month from June to October of the same year. Points along the portion of NR4 bordering Cataract Road (Figure 3) were derived by using the random formula described for the primary sampling program. The point-centred quarter sampling method (after Cottam and Curtis, 1956) was also used for both saplings and trees (only at 5 m) in order to ascertain sampling bias. Cottam and Curtis (1956) proposed that "as the basis of the point-centred quarter sampling method was the distance from the sample point to the nearest tree or sapling (irrespective of unusual size or appearance), this method was the least susceptible of various distance methods to subjective bias".

Spatial edge effects were determined for individual tree species as well as individual tree species grouped for all four areas, by the calculation of one-way parametric ANOVAs on dbh measurements. Spatial edge effects were determined for individual sapling species as well as individual sapling species grouped for all four areas by using Chi-Square contingency tables on size class distributions of dbh measurements. Minitab

version 8.0 was used for such calculations (Schaefer and Farber 1992). The replicates for this investigation were considered to be the sampling of the individual NR areas. The assumption used was that any differences between areas would not be significant and would not have an impact on the overall status of the absolute edges and the interiors.

Fig. 8. Point-Centred Quarter sampling method in which the distance from the sample point to the nearest tree and sapling is measured within each of four quadrants.
(after Cottam and Curtis, 1956).



Legend:
- ● - sampling point
- *s* - nearest sapling
- *t* - nearest tree
- 1 - quadrant
- – – – – - point to plant distance

RESULTS

Reliability: One-way analyses of variance (ANOVAs) were performed on tree dbh measurements and a Chi-Square ($\chi 2$) analysis (the rationale for performing this statistical analysis in the place of an ANOVA will be discussed later) was performed on the distribution of sapling dbh size classes (i.e. 2, 3, and 4 cm), both obtained during five sample days, which were conducted once a month in order to ascertain sampling bias. The **p** values (probability values) obtained from the one-way ANOVAs on tree dbh measurements are all > 5% (Table 1 - five sample days = independent variable; dbh = dependant variable). Due the small sample sizes of individual sapling species within each size class, a $\chi 2$ analysis could only be performed on all sapling species grouped together (Table 1). The **p** value obtained from this analysis is 0.795 which is also > 5% (Table 1). Therefore, it is likely that tree and sapling results obtained from each sampling day were similar. Therefore, it is reasonable to assume that no sampling bias occurred.

Part A. SPATIAL EDGE EFFECTS

All Species - Trees: In order to test the null hypothesis that there is no significant difference between dbh measurements taken at 5 and 25 m, a one-way ANOVA was performed on dbh data obtained at these two distances for all tree species grouped together from all four sample areas (Table 2 - 5 and 25 m = independent variable; dbh = dependant variable). The result of such an analysis for this variable (***all trees***) is a significant **p** value of < 0.001 (Table 2). In order to clarify the status of population normality, log and logit transformations were performed on the dbh data with normalization based on the largest individual dbh at either spatial distance. The **p** values obtained from subsequent one-way ANOVAs were also <0.001 (Appendix 1).

Individual Tree Species: In order to test the stated null hypothesis that there is no significant difference between measurements taken at 5 and 25 m, one-way ANOVAs

Table 1. Probability (p values) (at a 5% level of significance) obtained from one-way analyses of variance and Chi-Square Contingency Tables, performed on dbh measurements over a five month period (1992), in order to ascertain sampling bias.

Tree Species		**Date mean dbh values (s.d.)**									
	p value	**2-Jun**	***N***	**22-Jun**	***N***	**22-Jul**	***N***	**13-Sep**	***N***	**30-Oct**	***N***
All Trees	0.410	19.0 (8.6)	28	19.8 (6.2)	36	19.8 (8.0)	24	21.3 (7.6)	32	22.9 (10.4)	28
A. saccharum	0.732	15.4 (4.3)	10	16.9 (5.0)	13	18.0 (6.5)	8	17.6 (3.5)	11	15.7 (6.1)	11
F. americana	0.304	23.0 (0.0)	1	32.0 (0.0)	1	NA	NA	19.0 (5.7)	2	25.0 (0.0)	2
C. ovata	0.724	14.0 (0.0)	1	19.3 (7.2)	3	16.0 (6.1)	3	20.3 (5.5)	3	12.0 (0.0)	1
F. grandifolia	0.725	21.8 (11.8)	8	21.1 (7.0)	14	22.3 (10.0)	8	23.6 (7.5)	7	26.8 (11.0)	8
Q. rubra	0.428	33.0 (2.8)	2	21.0 (2.8)	2	24.0 (15.5)	2	39.0 (0.0)	1	41.0 (0.0)	1
T. americana	0.106	14.5 (2.1)	2	20.0 (1.4)	2	19.3 (2.5)	3	15.8 (1.3)	4	28.0 (12.0)	2
Q. alba	0.764	25.0 (3.5)	2	NA	NA	NA	NA	25.3 (2.1)	3	23.0 (0.0)	1
J. nigra	0.067	12.0 (0.0)	1	NA	NA	NA	NA	NA	NA	36.5 (2.1)	2

Table 1. cont.

Sapling Species

	Date	2.0 cm	3.0 cm	4.0 cm
All Saplings	2-Jun	11	9	8
	22-Jun	11	7	10
	22-Jul	10	3	4
	13-Sep	9	4	6
	30-Oct	6	3	1
$\chi 2=$	4.600		Critical Value (8 d.f.)= (Schefler, 1980)	15.507
$p=$	0.795			

Table 2. Probability (p values) obtained from one-way analyses of variance performed on dbh (cm) measurements of tree species.

* denotes significant values at 5%

Species	5 metres N	5 metres Mean dbh	5 metres S.D.	25 metres N	25 metres Mean dbh	25 metres S.D.	p value
All Trees	592	22.01	12.0	556	25.56	13.0	<0.001 *
A. saccharum	179	22.84	13.0	221	24.38	11.0	0.199
F. americana	70	22.06	9.0	68	31.28	12.0	<0.001 *
C. ovata	38	19.87	8.1	14	21.71	8.0	0.463
F. grandifolia	63	23.48	12.0	104	24.60	12.1	0.557
Q. rubra	33	33.52	19.0	24	43.71	22.0	0.066
T. americana	50	21.70	12.0	40	23.58	9.0	0.414
P. serotina	35	21.57	9.0	12	23.42	8.0	0.514
O. virginiana	60	14.82	6.3	33	14.73	4.8	0.944
U. americana	8	16.63	4.1	4	21.25	8.0	0.200
Q. alba	7	25.86	9.0	9	34.33	11.2	0.123

were performed on dbh data of individual tree species obtained at these two distances, and from all four sample areas (Table 2 - independent variable = 5 and 25 m; dependant variable = dbh measurements). A qualitative comparison of a systematic measure (i.e. importance value) for each individual species was also used for this purpose (the rationale for performing this comparison will be discussed later). *F. americana* is the sole tree species which has a significant **p** value at a level of 5% (Table 2). A comparison of mean importance values at 5 and 25 m, seems to indicate that *F. americana* is relatively less important at 5 m than at 25 m (Table 3). Table 3 indicates all shade-tolerant species for which importance values could be calculated (i.e. *A. saccharum* and *F. grandifolia*) are relatively more important at 25 m than at 5 m. Table 3 also shows that all shade-intolerant species (with the exception of *F. americana*) for which importance values could be calculated (i.e. *T. americana* L. (syn. T. glabra Vent) (basswood), *P. serotina* Ehrh. (black cherry);*Q. rubra* and *C. ovata*) are relatively more important at 5 m than at 25 m.

All Species - Saplings: In order to test the null hypothesis that there is no significant difference between measurements taken at 5 and 25 m, a $\chi 2$ analysis was performed on the distribution of dbh size classes obtained at these two distances, from all four sample areas, for all sapling species grouped together. The result of the $\chi 2$ analysis for this variable (***all saplings***) is a significant **p** value of 0.004 (Table 4).

Individual Sapling Species: In order to test the null hypothesis that there is no significant difference between measurements taken at 5 and 25 m, $\chi 2$ analyses were performed on the distribution of dbh size classes obtained at these two distances, from all four sample areas, for individual sapling species. A qualitative comparison of importance values for each individual species was also used for this purpose (Table 3). $\chi 2$ results show that *A. saccharum* is the only individual species which has a significant **p** value (Table 4). Table 3 indicates that all shade-tolerant species for which importance values could be calculated (i.e. *A. saccharum* and *F. grandifolia*) are relatively more important at 25 m than at 5 m.

Table 3. Importance values for individual tree and sapling species.

	5 metres						25 metres					
Tree Species	**NR1**	**NR2**	**NR4**	**NR5**	**Mean**	**S.D.**	**NR1**	**NR2**	**NR4**	**NR5**	**Mean**	**S.D.**
A. saccharum	1.24	0.62	0.88	0.98	**0.93**	**0.3**	1.32	0.95	0.95	1.36	**1.15**	**0.2**
F. americana	0.25	0.48	0.32	0.31	**0.34**	**0.1**	0.53	0.34	0.41	0.58	**0.47**	**0.1**
T. americana	0.28	0.28	0.28	0.19	**0.26**	**0.0**	0.17	0.19	0.33	0.08	**0.19**	**0.1**
F. grandifolia	0.77	0.29	0.46	0.18	**0.43**	**0.3**	0.64	0.64	0.55	0.22	**0.51**	**0.2**
P. serotina	0.08	0.2	0.21	0.14	**0.16**	**0.1**	0.1	0.11	0.03	0.09	**0.08**	**0.0**
Q. rubra	0.33	0.19	0.28	0.22	**0.26**	**0.1**	0.13	0.17	0.32	0.22	**0.21**	**0.1**
C. ovata	0.37	0.12	0.1	0.39	**0.25**	**0.2**	0.07	0.07	0.1	0.04	**0.07**	**0.0**
Sapling Species												
A. saccharum	1.45	1.33	0.81	1.22	**1.20**	**0.3**	1.51	1.57	1.24	1.72	**1.51**	**0.2**
F. grandifolia	0.28	0.25	0.98	0.15	**0.42**	**0.4**	0.7	0.79	1.17	0.73	**0.85**	**0.2**

Table 4. Probability (p values) obtained from Chi-Square Contingency Tables performed on dbh (cm) size class distribution of sapling species.

* denotes significant values at 5%

	5 metres			25 metres				
Species	**2.0 cm**	**3.0 cm**	**4.0 cm**	**2.0 cm**	**3.0 cm**	**4.0 cm**	$\chi 2$	**p value**
All Saplings	194	174	105	128	122	119	10.858	0.004 *
A. saccharum	85	68	32	51	65	62	18.014	< 0.001 *
F. grandifolia	38	32	23	49	38	33	0.273	0.872
F. americana	13	11	7	4	3	1	0.417	0.811
C. caroliniana	8	9	5	5	9	6	0.690	0.708
O. virginiana	22	23	22	7	4	10	2.180	0.336
T. americana	5	3	4	5	1	1	1.600	0.450

note: the critical value for 2 d.f. and a 5% level of significance is 5.991 (Schefler, 1980)

Part B. TEMPORAL EDGE EFFECTS

A qualitative comparison of mean importance values for both trees and saplings from all four sample areas (Table 3), allowed for an evaluation of possible temporal edge effects. *A. saccharum* saplings appear to be relatively more important than trees at both 5 and 25 m (Table 3). The relative importance of *F. grandifolia* trees and saplings at 5 m are similar (Table 3). However, it appears that the relative importance of *F. grandifolia* saplings is greater than that of the trees at 25 m (Table 3). There is some indication that *A. saccharum* may be exhibiting a temporal edge effect at both 5 and 25 m. There is also some indication that *F. grandifolia* may be exhibiting a temporal edge effect at 25 m.

An additional table of results (Table 5) indicates the sample sizes and mean dbh measurements of ***all trees*** and ***all saplings***, as well as those of individual tree and sapling species. In addition, Table 5 denotes whether or not an individual tree or sapling species is shade- tolerant (e.g. prefers a relatively shaded, moist habitat) or shade-intolerant (e.g. prefers a relatively sunny, dry environment) (after Baker, 1949). The implications of this table will be drawn out in the discussion section.

Table 5. Number, mean dbh (cm) and shade tolerance of tree and sapling species at 5 and 25 m.

Saplings

Species	Mean Dbh (s.d.) 5 metres	*N*	25 metres	*N*	Tolerant	Intolerant
All Saplings	2.81 (0.8)	473	2.97 (0.8)	369		
Alnus rugosa	2.00 (0.0)	1	NA	0	*	
Viburnum recognitum	NA	0	2.30 (0.6)	3	*	
Fraxinus americana	2.84 (0.8)	32	2.62 (0.7)	8		*
Carpinus caroliniana	2.86 (0.7)	22	3.05 (0.8)	20	*	
Tilia americana	2.92 (0.9)	12	2.43 (0.8)	7		*
Fagus grandifolia	2.84 (0.8)	93	2.87 (0.8)	120	*	
Carya laciniosa	2.00 (0.0)	3	NA	0		*
Rhamnus cathartica	3.33 (0.6)	3	NA	0		*
Betula papyrifera	2.50 (1.0)	4	NA	0		*
Betula alleghaniensis	2.00 (0.0)	2	NA	0	*	
Prunus serotina	3.30 (1.2)	3	NA	0		*
Prunus virginiana	2.50 (0.7)	2	NA	0		*
Prunus cerasus	2.00 (0.0)	1	NA	0		*
Cornus florida	2.67 (0.6)	3	2.00 (0.0)	2	*	
Ulmus rubra	2.67 (1.2)	3	3.30 (1.1)	3		*
Ulmus americana	3.25 (0.5)	4	4.00 (0.0)	1		*
Crataegus mollis	3.25 (1.0)	4	NA	0		*
Ostrya virginiana	3.00 (0.8)	67	3.14 (0.9)	21	*	
Acer saccharum	2.72 (0.7)	185	3.06 (0.7)	178	*	
Acer rubrum	1.25 (0.7)	2	NA	0	*	
Quercus rubra	2.70 (0.6)	3	NA	0		*
Pinus strobus	2.00 (0.0)	1	NA	0	*	
Amelancheir arborea	2.50 (0.7)	2	NA	0	unknown	unknown
Carya ovata	2.90 (0.6)	9	2.00 (0.0)	2		*
Juglans nigra	3.50 (0.7)	2	NA	0		*

Trees

Species	Mean Dbh (s.d.) 5 metres	*N*	25 metres	*N*	Tolerant	Intolerant
All Trees	22.01 (12.0)	592	25.56 (13.0)	556		
Fraxinus nigra	NA	0	23.00 (0.0)	1		*
Malus sylvestris	19.80 (13.0)	4	14.00 (0.0)	1		*
Fraxinus americana	22.06 (9.0)	70	31.28 (12.0)	68		*

Table 4. Cont.

Species	Mean Dbh (s.d.) 5 metres	*N*	25 metres	*N*	Tolerant	Intolerant
Carpinus caroliniana	14.00 (4.0)	7	NA	0	*	
Tilia americana	21.7 (12.0)	50	23.58 (9.0)	40		*
Fagus grandifolia	23.48 (12.0)	63	24.60 (12.0)	104	*	
Carya laciniosa	38.00 (0.0)	1	NA	0		*
Rhamnus cathartica	12.00 (0.0)	1	NA	0		*
Betula papyrifera	13.30 (4.1)	3	28.00 (14.7)	3		*
Betula alleghaniensis	NA	0	26.00 (14.1)	2	*	
Prunus serotina	21.57 (8.6)	35	23.42 (7.6)	12		*
Prunus virginiana	NA	0	28.50 (6.4)	2		*
Prunus cerasus	14.00 (0.0)	1	NA	0		*
Cornus florida	NA	0	10.00 (0.0)	1	*	
Ulmus rubra	NA	0	11.50 (0.71)	2		*
Ulmus americana	16.63 (4.1)	8	21.25 (8.0)	4		*
Tsuga canadensis	30.60 (16.1)	5	25.20 (10.0)	5	*	
Ostrya virginiana	14.82 (6.3)	60	14.73 (4.8)	33	*	
Juniperus horizontalis	16.00 (0.0)	1	NA	0	*	
Acer nigrum	NA	0	10.00 (0.0)	1	*	
Acer saccharum	22.84 (13.0)	180	24.38 (11.0)	222	*	
Acer rubrum	14.60 (5.0)	5	NA	0	*	
Quercus muehlenbergii	NA	0	22.00 (0.0)	1		*
Quercus rubra	33.52 (18.9)	33	43.71 (22.0)	24		*
Quercus alba	25.86 (8.8)	7	34.33 (11.2)	9		*
Populus grandidentata	21.43 (6.2)	14	27.33 (3.8)	3		*
Pinus strobus	19.00 (0.0)	1	50.00 (0.0)	1	*	
Sassafrass albidum	NA	0	23.00 (0.0)	1		*
Carya ovata	19.87 (8.1)	38	21.71 (7.6)	14		*
Rhus typhina	NA	0	10.00 (0.0)	1		*
Juglans nigra	34.75 (21.0)	4	47.00 (23.0)	2		*

DISCUSSION

Part A. SPATIAL EDGE EFFECTS

All Species - Trees:

The result of a one-way ANOVA conducted on the dbh measurements of ***all trees*** (Table 2) suggests that there is a significant difference between the mean dbh measurements of this variable at 5 and 25 m (Table 5). This may indicate that the wooded islands within Short Hills Provincial Park are exhibiting significant spatial edge effects.

A primary assumption of all ANOVAs is that populations from which observations are taken must be normally distributed. For example, 68% of values must lie within 1 standard deviation from the mean; 95% must lie within 2 standard deviations from the mean and 99% must lie within 3 standard deviations from the mean (Sokal and Rohlf, 1980). The normality of the ***all trees*** population was considered questionable (Perera, pers. comm., 1994) due to the size selection criteria used (i.e. a minimum size of 10.0 cm dbh was required for a woody stem to be considered as a tree). It was proposed that to compensate for any deviations from normality, log or logit transformations should be performed on the dbh data (Appendix 1) and that the one-way ANOVA be repeated on the ***all trees*** variable (Perera, pers. comm., 1994). Recalculations of one-way ANOVAs based upon both sets of transformed data (Appendix 1) yielded **p** values identical to that obtained from the non-transformed data shown in Table 2. Hence, the transformation results suggest that deviations from normality are largely not relevant to the dbh measurements of the ***all trees*** and that conclusions of a significant spatial edge effect for this variable are valid.

These data suggest that the ***all trees*** variable may be exhibiting a significant spatial edge effect within the forest islands of Short Hills Provincial Park (Table 2). One possible explanation for this may be the biological attributes of the major species which comprise this variable.

When conducting one-way ANOVAs on individual tree and sapling species, the single treatment or condition difference used is the spatial distance of 5 and 25 m (including confounding factors at each distance such as microclimate, seed dispersal, wind and sunlight penetration etc.). Further, if assuming that large-scale, relatively constant variables such as climate and soil conditions are equal (e.g. those variables which should generally not differ as a function of edge depth), it is proposed that any significant variation observed between 5 and 25 m would be attributable to the spatial distance.

While this conclusion would hold true for the analyses of individual species, the significant result obtained for ***all trees*** are complicated by an uncontrolled variable, specific to populations composed of mixed species. Figure 9 indicates the difference in species composition for ***all trees*** from all four sample areas, at 5 and 25 m. Unlike a single species population in which mean dbh measurements may reflect various physical, chemical and biological differences, the mean dbh of mixed species populations may also be affected by differences in the numbers of individual species comprising those populations. For example, 60 and 33 *Ostrya virginiana* (Mill.) K. Koch (hop hornbeam) trees were sampled at 5 and 25 m respectively; the mean dbh of these trees varied little as compared to the mean dbh measurements of ***all trees*** at 5 and 25 m (Tables 2 and 5). While the dbh measurements of *O. virginiana* at 5 and 25 m are not significantly different from each other (Table 2), the larger number of trees at 5 m serves to reduce the overall mean of ***all trees*** as opposed to that at 25 m. Conversely, 63 and 104 *F. grandifolia* trees were sampled at 5 and 25 m respectively. Similarly, the mean dbh measurements of this species at 5 and 25 m varied little from each other (Tables 2 and 5), as compared to the mean dbh measurements of ***all trees*** at 5 and 25 m (Tables 2 and 5). While the dbh measurements of *F. grandifolia* at 5 and 25 m are not significantly different from each other, the larger number of trees at 25 m serves to increase the overall mean dbh of ***all trees*** at 25 m as opposed to that at 5 m.

Fig. 9. A comparison of the Species Composition of the ***All Trees*** variable at 5 and 25 metres for all four sample areas.

Ab	*Fraxinus nigra*
Ap	*Malus sylvestris*
Aw	*Fraxinus americana*
Bb	*Carpinus caroliniana*
Bd	*Tilia americana*
Be	*Fagus grandifolia*
Bsh	*Carya laciniosa*
Bu	*Rhamnus cathartica*
Bw	*Betula papyrifera*
By	*Betula alleghaniensis*
Cb	*Prunus serotina*
Cc	*Prunus virginiana*
Cs	*Prunus cerasus*
Dg	*Cornus florida*
Es	*Ulmus rubrum*
Ew	*Ulmus americana*
He	*Tsuga canadensis*
Id	*Ostrya virginiana*
Ju	*Juniperus horizontalis*
Mb	*Acer nigrum*
Mh	*Acer saccharum*
Ms	*Acer rubrum*
Och	*Quercus meuhlenbergii*
Or	*Quercus rubra*
Ow	*Quercus alba*
Po	*Populus grandidentata*
Pw	*Pinus strobus*
Sa	*Sassafras albidum*
SHi	*Carya ovata*
Su	*Rhus typhina*
Wb	*Juglans nigra*

Number of Trees
0
50
100
150
200
250
Ab
Ap
Aw
Bb
Bd
Be
Bsh
Bu
Bw
By
Cb
Cc
Cs
Dg
Es
Ew
He
Id
Ju
Mb
Mh
Ms
Och
Or
Ow
Po
Pw
Sa
SHi
Su
Wb

Individual Tree Species: Results of ANOVAs conducted on dbh measurements of individual tree species show that the majority do not have significant **p** values (Table 2). *F.americana* is the sole tree species which has a significant **p** value (Table 2), this suggests that there is a significant difference between the mean dbh measurements of this species at 5 and 25 m (Table 5). In addition to the ANOVAs conducted on dbh measurements, it was proposed that importance values (indices comprised of three relative numbers i.e. relative density, relative dominance and relative frequency) at 5 and 25 m also be used (in a qualitative manner) in order to determine the possible exhibition of spatial edge effects by individual tree species (Muller and Huang, pers. comm., 1994). This approach is in keeping with past studies of forested ecosystems in which differences in mean importance values were established qualitatively (e.g. Cottam and Curtis, 1956; Levenson, 1980).

A qualitative comparison of mean importance values of *F.americana* trees at 5 and 25 m (Table 3) seems to substantiate dbh ANOVA results, suggesting that populations of this species may be exhibiting significant spatial edge effects within the wooded islands of Short Hills Provincial Park. While this species is normally considered to be shade-intolerant (Baker, 1949) and is thus more typical of an edge environment, Table 3 suggests that this species of tree is relatively less important at 5 m than at 25 m. In addition, Table 5 indicates that larger *F.americana* trees are located at 25 m rather than at 5 m and that the number of trees found at both spatial distances are virtually identical. Despite the shade-tolerant nature of this species, such results may not be unexpected. The presence of *F. americana* trees in interior areas is "often attributed to the ability of this species to persist in dense shade until a canopy opening occurs" (Cope, 1948). "Vigorous reproduction of this species is maintained for at least 15 years when growing under canopy openings or under light canopies having high height with either medium or thin density. Hence, the seedling reproduction of *F.americana* is considered to be relatively shade-tolerant" (Guenther,

1951). The utilization of such canopy gaps over a number of years may have contributed to its elevated occurrence in the island interiors.

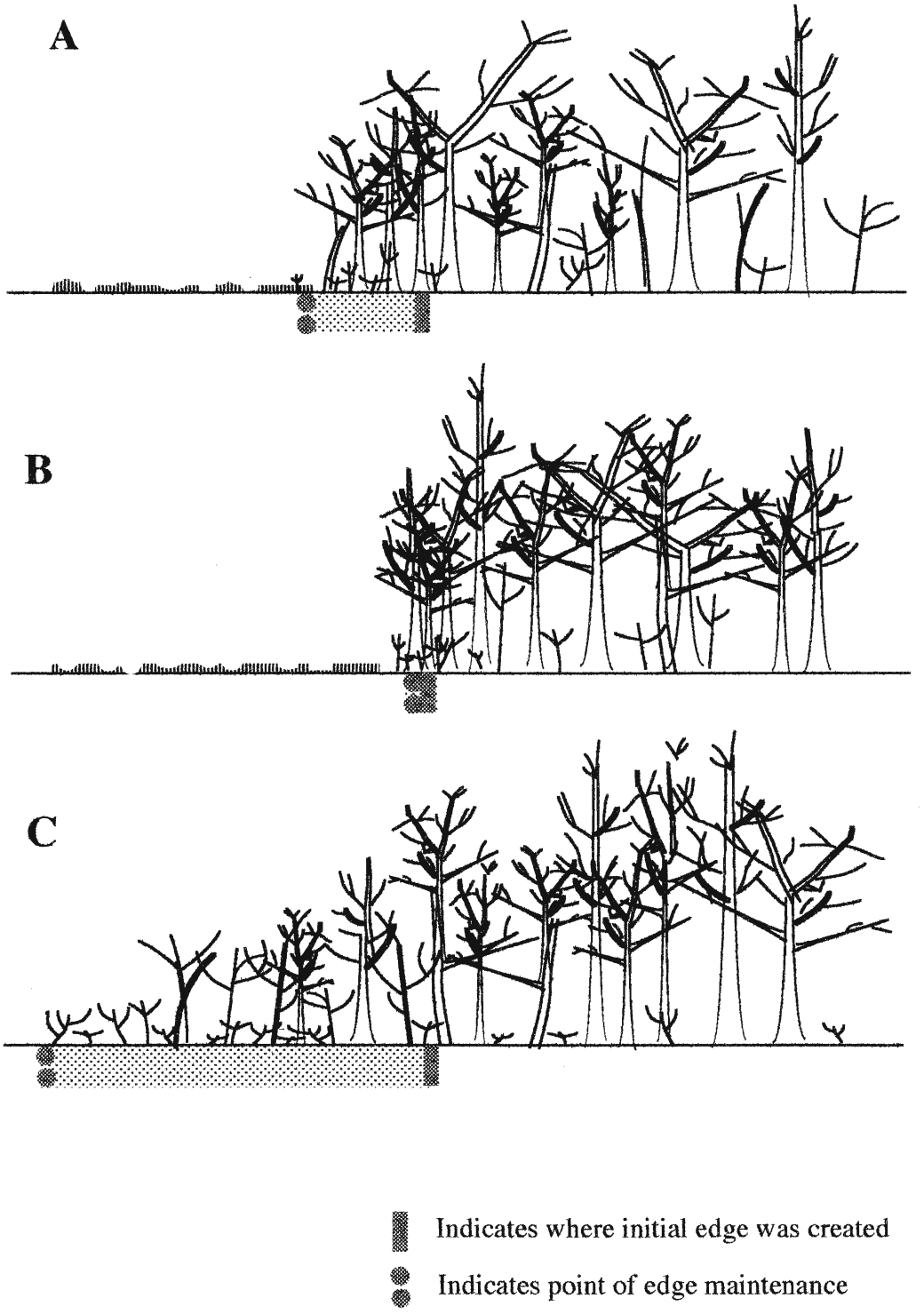
Gysel (1951) observed that edges could be maintained in several ways (Figure 10). "Some edges may be maintained at the outer dripline of edge canopy trees (i.e. canopy dripline edges), while others are maintained either at the base of edge canopy trees (i.e. cantilevered edges), or beyond the tree dripline (i.e. advancing edges)" (Gysel, 1951). The initial edges of those forests which have advancing edges may become obscured over time. Subsequently, vegetation within the area of advancing edge might have characteristics similar to that of the forest interior. A strong indication of an original edge within a forest would be the presence of large, shade-intolerant tree species within shaded, interior habitats.

Wales (1972) observed an increased density of relatively large, shade-intolerant trees (e.g. *Quercus* spp.) at 10-20 m in the interior of a mature forest in New Jersey, U.S.A. . It was subsequently concluded that "such trees formed the original edges of the forest area" (Wales, 1972). The presence of *F. americana* at the 25 m distance may also be attributed to such a phenomenon. Their location may represent original edges within the park's forest islands, which have since been obscured by a relatively more recent edge. Former edge trees have been observed to "have characteristics common to those trees which border forest islands, namely, asymmetrical boles with considerable clear-length on the interior side and heavy branching to the outside" (Levenson, 1981). The investigation of initial edges within the forest islands of the park, could form the basis for future studies.

While the results of ANOVAs performed on dbh data show that no other shade-intolerant tree species (after Baker, 1949) have significant **p** values, Table 3 indicates differences in the mean importance values for shade-intolerant species (after Baker, 1949) such as *T. americana*; *P. serotina*; *Q. rubra* and *C. ovata*. Without exception, such species appear to be relatively more important as compared to other species at 5 m than at 25 m, within the studied forest islands of Short Hills Provincial Park (Table 3). As well, Table 5

Fig. 10. Three commonly observed Edge maintenance types in relation to the point of initial edge creation: A. Canopy Dripline, B. Cantilevered, C. Advancing

(after Ranney et. al., 1981)


A
B
C
Indicates where initial edge was created
Indicates point of edge maintenance

shows that these species are in greater abundance at 5 m as opposed to 25 m. These results are in keeping with previous studies concerning the vegetation of fragmented forest islands. Levenson, 1981; Ranney, 1978; Ranney et al., 1981 and Brothers, 1993, have noted the proliferation of these species in the drier, sunnier edges of forest islands and their relative decline in numbers in forest interiors. The reproductive strategies of such species often contributes to their prevalence within edge habitats. For example, prolific vegetative stump sprouting of large *T. americana* trees ensures this species as a successful edge inhabitant (Ranney, 1978). The basal area of such tree species have been found to be 300% greater in forest island edges as compared to interiors (Ranney et al., 1981).

Based upon the qualitative analysis of mean importance values of the above-noted shade-intolerant trees (Table 3) it may be proposed that while ANOVA results show that they do no have significant **p** values (Table 2), these species may still be exhibiting some sort of spatial edge effect within the sampled wooded islands of Short Hills Provincial Park. While perhaps this analysis in isolation does not quantitatively illustrate significant spatial edge effects, it is proposed that qualitative results tend to support the overall significant spatial edge effect noted for ***all trees*** (Table 2).

Table 3 also indicates differences in mean importance values for shade-tolerant tree species (after Baker, 1949) such as *A. saccharum* and *F. grandifolia*. Both of these species appear to more important at 25 m relative to other tree species than at 5 m. In addition, Table 5 indicates that more individuals of these species occur at 25 m than at 5 m. These results are in keeping with previous studies concerning the vegetation of fragmented forest islands. Both *A. saccharum* and *F. grandifolia* have been previously found to be typical of interior, moist (mesic) habitats and have been found to decline in forest island edges (e.g. Levenson, 1981; Ranney et al., 1981; Brothers, 1993). Levenson (1981) proposed that if interiors of wooded islands were sufficiently large enough to maintain acceptable conditions for *A. saccharum* and *F. grandifolia* (i.e. >2.3 ha), than they would be greatly favoured over species which are less shade-tolerant. Conversely, *F. grandifolia* is

normally "rejected" in smaller interior areas in deference to species which can exist within an edge environment (e.g. Levenson, 1980 and 1981; Ranney et al., 1981).

Ranney (1978) and Ranney et al. (1981) proposed that the lack of reproductive success of *F. grandifolia* has accounted for its elimination from edge-bordered interiors. Conditions which were thought to represent small islands (1-2 ha) were found to be beyond the species' tolerance limits (Ranney, 1978 and Ranney et al., 1981). The study area (southeastern Wisconsin) utilized by Levenson (1980 and 1981); Ranney (1978) and Ranney et al. (1981) is at the extreme edge of the range for *F. grandifolia.* Therefore, the relative lack of this species in island edge habitats may simply be a reflection of its inability to prosper in this particular area (Ranney, 1978). Therefore, the results of the above-noted studies may have geographical validity, but perhaps not species validity (Ranney, 1978).

Both Table 5 and Figure 9 show that while *A. saccharum* and *F. grandifolia* trees are more numerous at 25 m than they are at 5 m, both species still occur in fairly large numbers at the edges of the sample forest islands of Short Hills Park. As the Niagara region is well within the geographical range of *F. grandifolia* (Hosie, 1975), these results may support the possibility that the observations of Ranney (1978) and Ranney et al. (1981) are affected by the geographical location of their study area. Depending on the amount of time which has lapsed since the major disturbances in the Short Hills Park, these results may also contradict the general theory that disturbance reduces the amount of available interior habitat in heterogeneous landscapes (Figure 1) and thus reduces the amount of shade-tolerant vegetation (e.g. Elfstrom, 1976; Levenson, 1981; Ranney et al., 1981; Forman, 1982; Harris, 1984 and Forman and Godron, 1986). All four sample areas are greater in size than 2.3 ha, the minimum area proposed by Levenson (1981) as necessary for the survival of *F. grandifolia* populations.

ANOVA results show that similar to shade-intolerant tree species such as *T. americana*; *P. serotina*; *Q. rubra* and *C. ovata*, the shade-tolerant species noted above do not have significant **p** values (Table 2). As well, Table 5 and Figure 9 indicate that

relatively large numbers of *A. saccharum* and *F. grandifolia* are present at 5 m. However, both species are relatively more important at 25 m than at 5 m (Table 3). Despite the presence of evidence somewhat to the contrary, it is still proposed that these species may be exhibiting some sort of spatial edge effect within the sampled wooded islands of Short Hills Provincial Park. Similar to the results noted for shade-intolerant species, the analysis of the mean importance values of shade-tolerant tree species in isolation does not quantitatively illustrate significant spatial edge effects. However, it is proposed that the qualitative results tend to support the overall significant spatial edge effect noted for ***all trees*** (Table 2).

All Species - Saplings:

The result of a $\chi 2$ analysis conducted on the dbh size class distribution of ***all saplings*** (Table 4) suggests that there is a significant difference between the size class distribution of this variable at 5 and 25 m. This may indicate (in addition to the ***all trees*** analysis) that the wooded islands within Short Hills Provincial Park are exhibiting significant spatial edge effects.

The normality of the ***all saplings*** population was considered questionable (Perera, pers. comm., 1994) due to the restrictive nature of the size criteria used (i.e. 2, 3, and 4 cm dbh). It was therefore proposed that a $\chi 2$ Contingency Table (Table 4) be used to determine significant differences in the distribution of 2, 3, and 4 cm dbh saplings (for ***all saplings*** as well as individual species) at 5 and 25 m as an alternative to the performance of an ANOVA (Muller and Huang, pers. comm., 1994).

Statistical results suggest that the ***all saplings*** variable may be exhibiting a significant spatial edge effect within the forest islands of Short Hills Provincial Park (Table 4). One possible explanation for this may lie in the significant result noted for *A. saccharum* saplings (Table 4). Table 5 indicates that *A. saccharum* has the largest population size of all sapling species at both 5 and 25 m and comprises 44% of the ***all saplings*** variable. In addition, Table 4 indicates that the greatest number of saplings

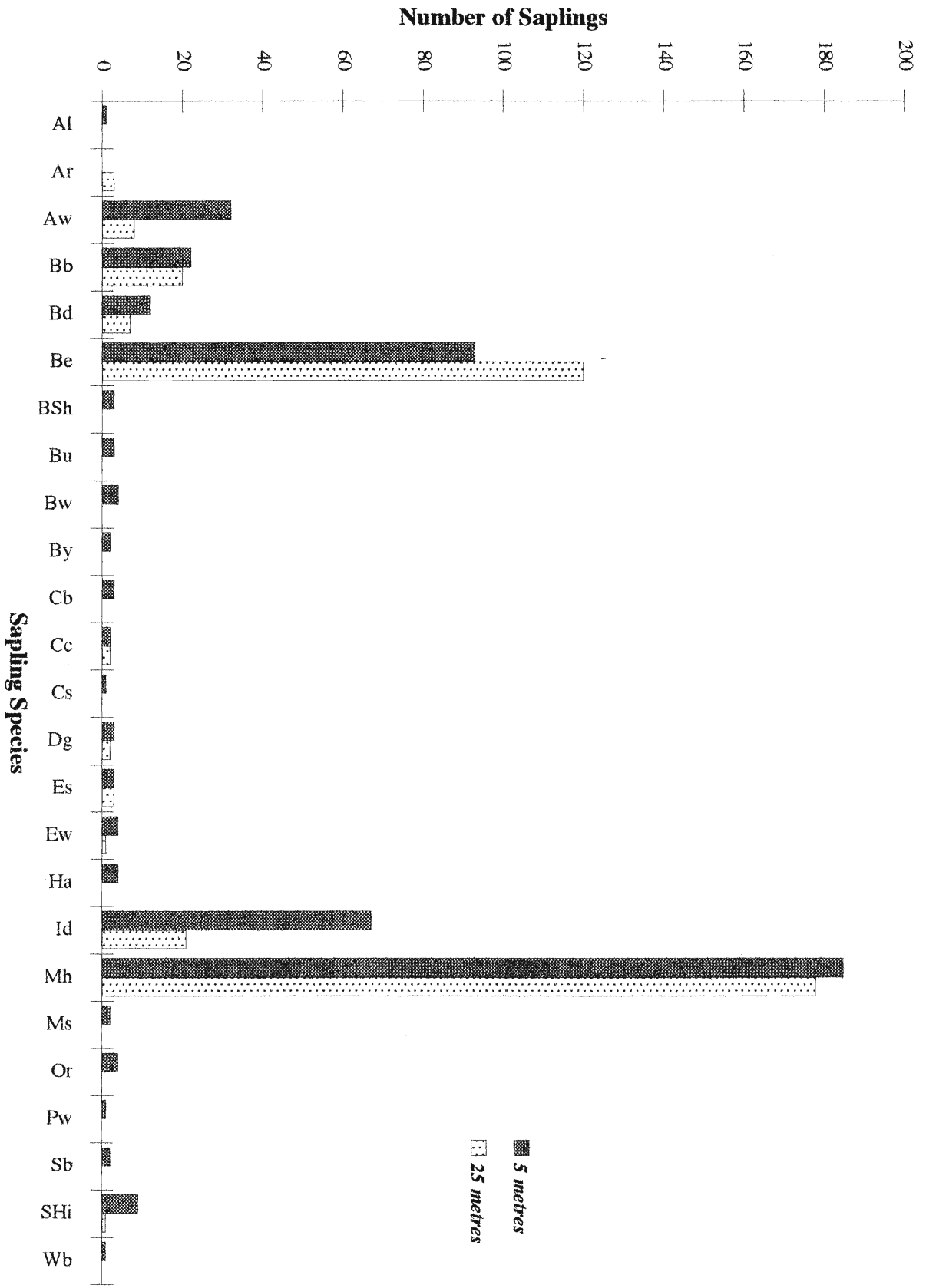
comprising the 2, 3 and 4 cm size classes at both 5 and 25 m are *A. saccharum* saplings. This species also appears to be the most important sapling species relative to others, at both 5 and 25 m (Table 3). Thus, the apparent dominance of this sapling species in concert with its significantly different size class distribution at 5 and 25 m (Table 4), may indicate that ***all saplings*** derives its spatial edge effect, largely from *A. saccharum* .

As proposed for ***all trees***, another possible explanation for the spatial edge effect noted for ***all saplings*** may the biological attributes of the major species which comprise this variable. Similarly, the significant result obtained for ***all saplings*** may also be complicated by an uncontrolled variable, specific to populations composed of mixed species.

The *F.americana* sapling population may be used as example of such an uncontrolled variable. The size class distribution of this species was not significantly different as compared to the size class distribution of ***all saplings*** at 5 and 25 m (Table 4). Both Tables 4 and 5 as well as Figure 11 illustrate that with respect to the species composition for ***all saplings*** , 32 and 8 *F.americana* saplings were sampled at 5 and 25 m. While the size class distribution of *F.americana* at 5 and 25 m are not significantly different from each other (Table 4), the increased amount of saplings at 5 m serves to decrease the overall weighted mean of ***all saplings*** at 5 m as opposed to that at 25 m. The *F. grandifolia* sapling population may be used as another example. The size class distribution of this species was not significantly different as compared to the size class distribution of ***all saplings*** at 5 and 25 m (Table 4). Tables 4 and 5 and Figure 11 indicate that with respect to the species composition for ***all saplings***, 93 and 120 *F. grandifolia* saplings were sampled at 5 and 25 m. While the size class distribution of *F. grandifolia* at 5 and 25 m are not significantly different from each other (Table 4), the increased amount of saplings at 25 m serves to increase the overall weighted mean of ***all saplings*** as opposed to that at 5 m.

Fig. 11. A comparison of the Species Composition of the ***All Saplings*** variable at 5 and 25 metres for all four sample areas

Al	*Alnus rugosa*
Ar	*Virburnum recognitum*
Aw	*Fraxinus americana*
Bb	*Carpinus caroliniana*
Bd	*Tilia americana*
Be	*Fagus grandifolia*
Bsh	*Carya laciniosa*
Bu	*Rhamnus cathartica*
Bw	*Betula papyrifera*
By	*Betula alleghaniensis*
Cb	*Prunus serotina*
Cc	*Prunus virginiana*
Cs	*Prunus cerasus*
Dg	*Cornus florida*
Es	*Ulmus rubrum*
Ew	*Ulmus americana*
Ha	*Crataegus sp.*
Id	*Ostrya virginiana*
Mh	*Acer saccharum*
Ms	*Acer rubrum*
Or	*Quercus rubra*
Pw	*Pinus strobus*
Sb	*Amelancheir sp.*
SHi	*Carya ovata*
Wb	*Juglans nigra*


Number of Saplings
0
20
40
60
80
100
120
140
160
180
200
Sapling Species
Al
Ar
Aw
Bb
Bd
Be
BSh
Bu
Bw
By
Cb
Cc
Cs
Dg
Es
Ew
Ha
Id
Mh
Ms
Or
Pw
Sb
SHi
Wb
5 metres
25 metres

Individual Sapling Species: Results of $\chi 2$ analyses on size class distributions of individual sapling species show that the majority do not have significant **p** values (Table 4). *A. saccharum* is the sole sapling species which has a significant **p** value (Table 4), this suggests that there is a significant difference between the size class distribution of this species at 5 and 25 m. A qualitative comparison of mean importance values for *A. saccharum* saplings at 5 and 25 m (Table 3) suggests that this species is relatively more important at 25 m than it is at 5 m. This seems to substantiate the $\chi 2$ results, suggesting that populations of this species may be exhibiting significant spatial edge effects within the wooded islands of Short Hills Provincial Park.

The fact that *A. saccharum* saplings appear to be relatively more important at 25 m as opposed to 5 m is not unexpected. As previously noted, this species is considered to be shade-tolerant (after Baker, 1949) and hence, prefers the shaded, mesic habitat of forest island interiors. However, Table 5 and Figure 11 indicate that *A. saccharum* saplings are slightly more numerous at 5 m than they are at 25 m. This is inconsistent with previous studies in which sapling populations of *A. saccharum* were generally observed to be more numerous in the interiors of forest islands (Levenson, 1981; Ranney et al., 1981; Brothers, 1993). However, Ranney (1978) noted that in forest islands of southeastern Wisconsin, *A. saccharum* had similar regeneration patterns in interior and edge areas. In order for this to occur, it was proposed that island edges should have a soil moisture content equalling or exceeding that associated with 51.0 cm of annual precipitation. When *A. saccharum* individuals attained a dbh of 20 cm, a considerable contrast was then observed between the interior and edge distribution of this species (Ranney, 1978). The pattern noted by Ranney (1978) may be reflected by the *A. saccharum* sapling population within the studied forest islands of Short Hills Park. While the soil moisture content of the forest islands at 5 and 25 m was not measured, it may be conceivable that the soil moisture content at 5 m was of a sufficient nature to have provided the basis for increased *A. saccharum* regeneration at this spatial distance. The contrasting tree distribution between 5 and 25 m (Figure 9) seems

to support Ranney's (1978) observations that larger *A. saccharum* individuals exhibit different compositional patterns at forest island interiors and edges.

F. grandifolia was the only other sapling species for which importance values could be calculated. While this species did not have a significant **p** value as a result of $\chi 2$ analysis, Table 3 indicates that it is relatively more important at 25 m than it is at 5 m. Similar to *A. saccharum* , the fact that *F. grandifolia* saplings appear to be relatively more important at 25 m as opposed to 5 m is not unexpected. As previously noted, this species is considered to be shade-tolerant (after Baker, 1949) and hence, prefers the shaded, mesic habitat of forest island interiors. This species is also more numerous at 25 m than it is at 5 m (Table 5 and Figure 11), a pattern which is consistent with previous studies on forest fragmentation (Levenson, 1981; Ranney et al., 1981; Brothers, 1993). Similar to its tree population, a relatively large number of *F. grandifolia* saplings are still found at 5 m (Table 5 and Figure 11). This result may also serve to contradict the observations of Levenson (1980 and 1981); Ranney (1978) and Ranney et al. (1981), who found that sapling populations of *F. grandifolia* were relatively small in the edge areas of forest islands as compared to interior areas. As previously mentioned, the relative lack of this species within island edge habitats in the past studies noted above may a reflection of *F. grandifolia*'s inability to prosper in the geographical area used in these studies (i.e. southeastern Wisconsin which is at the extreme edge of the range for this species). Conversely, the Niagara region is well within the geographical range of *F. grandifolia* (Hosie, 1975). In a fashion similar to the species' tree population, the relatively large amount of *F. grandifolia* saplings in the edge areas of the studied forest islands of Short Hills Provincial Park, seems to somewhat contradict the general theory that interior habitat (and subsequently shade-tolerant vegetation) is reduced within heterogeneous landscapes (Figure 1 - e.g. Elfstrom, 1976; Levenson, 1981; Ranney et al., 1981; Forman, 1982; Harris, 1984 and Forman and Godron, 1986). However, apparent contradictions to this theory within the park may simply be a function of the amount of time which has lapsed

since the major disturbances in the Short Hills area. As previously mentioned, the studied forest islands of the park are of sufficient size (i.e. > 2.3 ha as proposed by Levenson, 1981) for the survival of *F. grandifolia.*

It has been proposed above that the significant spatial result noted for *A. saccharum* saplings (Table 4) quantitatively contributes to the overall spatial edge effect apparently experienced by the ***all saplings*** variable. It is also proposed that the mean importance values of this species at 5 and 25 m (Table 3), qualitatively supports both the *A. saccharum* and the ***all saplings*** result. Quantitatively, the statistical analysis of *F. grandifolia* saplings did not yield a significant result (Table 4). However, the qualitative assessment of its mean importance values at 5 and 25 m (Table 3) suggests that this species may be exhibiting some sort of spatial edge effect within the sampled wooded islands of Short Hills Provincial Park. This qualitative result may also tend to support the significant spatial edge effect proposed for the ***all saplings*** variable.

Based upon the significant differences between the exterior and the interior of the studied forest islands of Short Hills Provincial Park with respect to the mean dbh measurements of the ***all trees*** variable and the size class distribution of ***all saplings*** , it is proposed that the null hypothesis; **there is no significant difference between measurements taken at five and twenty-five metres as determined by statistical analyses** may be rejected.

Part B. TEMPORAL EDGE EFFECTS

A qualitative comparison of mean importance values for both trees and saplings from all four sample areas (Table 3) was used in order to evaluate the presence of a possible temporal edge effect within the sampled forest islands of Short Hills Provincial Park. Of all species sampled, only *A. saccharum* and *F. grandifolia* were able to undergo such a comparison.

Table 3 indicates that the relative importance of *A. saccharum* saplings is greater than that of trees for the majority of sample areas at both 5 and 25 m, with the exception of NR4 at 5 m. Therefore, the mean importance value of *A. saccharum* saplings appears to be greater than that of trees in an overall sense (Table 3). This may indicate that *A. saccharum* is exhibiting a temporal edge effect throughout Short Hills Provincial Park.

The higher importance values of *A. saccharum* saplings (Table 3) may indicate that they are relatively more important as compared to other species within the forest islands, than trees are. As the saplings currently observed are younger than their tree counterparts, it is proposed that they represent the future forests of Short Hills Provincial Park. Conversely, the trees are more likely to be reflective of the past. Therefore, as *A. saccharum* saplings seem to be more important relatively speaking then *A. saccharum* trees, the forest islands of Short Hills Provincial Park may become increasingly dominated by this species in the future. All else being equal, the existence of such a directional force could possibly be maintained even if there were no further changes to the park and it were left in its current state. In essence, where *A. saccharum* is concerned, the forest islands of the park seem to exist in a state of flux. Therefore, the temporal edge effect which appears to be exhibited by this species may indicate that the studied forest islands continue to respond to previous human disturbances within the park. It is proposed that if the forest islands had equilibrated over time, calculated importance values would probably be the same for this or any other species for both trees and saplings. Because of the growth characteristics of *A. saccharum*, the possibility of its continuing response to previous

disturbance may not be unexpected. As mentioned previously, *A. saccharum* has traditionally been viewed as shade-tolerant and hence, mesic in nature (Baker, 1949). However, this species also has the ability to take advantage of canopy openings in forest island interiors. *A. saccharum* seedlings have been observed to grow rapidly in such openings, therefore often ensuring the position of this species as the dominant inhabitant of many deciduous forests (Bray, 1956). As previously mentioned, the importance values of *A. saccharum* (Table 3) appears to confirm that it is both the dominant tree and sapling species of Short Hills Provincial Park.

Although the current conditions in which *A. saccharum* saplings have established themselves (i.e. since the late 1970's) are likely different from the conditions in which the mature trees (as saplings) were established, the biological nature of this species may have allowed it to maintain its position of dominance in these forest areas relative to other species over time. The previous landscape of the park was likely less fragmented, such conditions would have been optimal for such a characteristically shade-tolerant species. More recently, the landscape of the park appears to have become increasingly fragmented. However, due to its apparent ability to take advantage of canopy openings in forest island interiors, *A. saccharum* can also thrive in the xeric and warm conditions characteristic to such a situation. It may be inferred therefore, that this species can prosper in both pre- and post- disturbance forests.

Table 3 indicates that the relative importance of *F. grandifolia* saplings is greater than that of trees at 25 m, while there does not appear to be any difference between the importance values of *F. grandifolia* trees and saplings at 5 m. This may indicate that *F. grandifolia* is exhibiting some sort of temporal edge effect within the interior of the sampled wooded islands of Short Hills Provincial Park.

As previously mentioned, *F. grandifolia* is considered to be a shade-tolerant species (Baker, 1949) and hence, appears to prefer the mesic habitat of forest island interiors (Levenson, 1981; Ranney et al., 1981 and Brothers, 1993). Therefore, the environment at

25 m is likely to be suitable for an increased growth of *F. grandifolia.* This appears to be confirmed by the higher relative importance of saplings as compared to trees at this distance (Table 3). Conversely, the environment at 5 m is likely to be unsuitable for an increased growth of *F. grandifolia.* This appears to be confirmed by the almost identical importance values of trees and saplings at this distance (Table 3).

Based upon the differences observed between *A. saccharum* trees and saplings, with respect to importance values, it is proposed that the null hypothesis; **there is no significant difference between the measurements of trees and saplings as determined by qualitative analyses** may be rejected.

Part C. SUMMARY OF MAJOR FINDINGS

Quantitative analyses tend to indicate that grouped tree and sapling populations in sampled forest islands in Short Hills Provincial Park are exhibiting significant spatial edge effects. Qualitative comparisons of the importance values of certain individual tree and sapling species appear to support the quantitative analyses' results. Qualitative comparisons of the importance values of *A. saccharum* trees and saplings tend to indicate that this species is exhibiting a temporal edge effect within these islands.

The possible presence of both spatial and temporal edge effects may imply that forest fragmentation within the park has affected existing forest islands.

Landscape ecologists have proposed that three levels of approach be taken in order to determine specific characteristics of heterogeneous landscapes, namely; structural, functional and dynamic (Zonneveld, 1990). The structural basis of the results obtained in this thesis appear to be the interactions between the forest islands and adjacent land uses. There appears to be no functional basis for the results obtained as all edges were considered to be the same and were treated in a similar fashion. The dynamic basis for the results obtained appears to be reflected in the apparent *A. saccharum* temporal edge effect.

The heterogeneous nature of the park appears to be of importance in understanding this area as a complex, ecological system.

The possible existence of spatial and temporal edge effects within the forest islands of the park, poses several new questions which while out of the scope of this thesis, may be addressed in future research projects. For example, the species type and amount of propagule dispersal in concert with island isolation may promote edge effects (Ranney, 1978; Ranney et al., 1981). The mechanism by which propagule dispersal occurs (i.e. wind, bird or mammalian vectors), has been proven to be important in several forest fragmentation studies (Ranney and Johnson, 1977; Johnson and Adkisson, 1981; Albanese, 1987 and McDonnell, 1988).

Part D. MANAGEMENT RECOMMENDATIONS

In order to mitigate possible spatial and temporal effects within forest islands, to create increasing areas of mesic forest typical to the Eastern Deciduous Forest Region (after Rowe, 1959) and to preserve present forested areas, recommendations are made to the Ontario Ministry of Natural Resources concerning the ecosystem management of Short Hills Provincial Park.

A. To reduce possible spatial edge effects exhibited by the park's forest islands, buffer zones could be planted around each patch to allow interior areas to progress outward. In this manner, the perimeter to edge ratio of each island could be reduced. An increase in mesic habitat preferred by the dominant species *A. saccharum* and *F. grandifolia* may be achieved. As indicated by the differences observed between 5 and 25 m, the relatively small distance of 20 m may be ecologically significant. As a result, planted buffer zones may only need to be that wide. Native species characteristic of pioneer forests (e.g. *F. americana*, *T. americana*, and *P. serotina*) as well as various conifer species, have been previously recommended as suitable for such buffer zones (Ranney et al., 1981).

B. The possible temporal edge effect exhibited by *A. saccharum* within the park's forest islands may indicate that these areas continue to respond to previous disturbances. The changing nature of this species should be taken into account by the Ontario Ministry of Natural Resources when considering future management options for the park. The exhibition of a possible temporal edge effect by *A. saccharum* may implies that the forest islands within the park will alter internally, whether it be in the presence of or in the absence of human disturbance.

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Appendix 1: Output from Minitab showing one-way ANOVAs conducted on a) nontransformed ***all trees*** dbh values, b) log transformed ***all trees*** dbh values, c) logit transformed ***all trees*** dbh values. All calculations use edge depth (5 and 25 metres) as the independent variable.

a) Nontransformed *all trees* dbh one-way ANOVA results.

```
MTB > Oneway 'Dbh (cm)' 'Depth'.

ANALYSIS OF VARIANCE ON Dbh (cm)
SOURCE      DF        SS        MS        F        p
Depth        1      3615      3615    23.99    0.000
ERROR     1146    172664       151
TOTAL     1147    176279

                                       INDIVIDUAL 95 PCT CI'S FOR MEAN
                                       BASED ON POOLED STDEV
 LEVEL       N      MEAN     STDEV  ---------+---------+---------+-------
     5     592     22.01     11.96  (------*-----)
    25     556     25.56     12.60                       (------*-----)
                                       ---------+---------+---------+-------
POOLED STDEV =    12.27              22.4      24.0      25.6
```

b) Log transformed *all trees* dbh one-way ANOVA results.

```
MTB > Oneway 'log' 'Depth'.

ANALYSIS OF VARIANCE ON log
SOURCE      DF        SS        MS        F        p
Depth        1    1.3240    1.3240    31.87    0.000
ERROR     1146   47.6133    0.0415
TOTAL     1147   48.9373

                                       INDIVIDUAL 95 PCT CI'S FOR MEAN
                                       BASED ON POOLED STDEV
 LEVEL       N      MEAN     STDEV  ------+---------+---------+---------+
     5     592   -0.7215    0.2034  (-----*----)
    25     556   -0.6535    0.2042                       (----*-----)
                                       ------+---------+---------+---------+
POOLED STDEV =   0.2038            -0.720    -0.690    -0.660    -.63
```

c) Logit transformed *all trees* dbh one-way ANOVA results.

```
MTB > Oneway 'logit' 'Depth'.

ANALYSIS OF VARIANCE ON logit
SOURCE      DF        SS        MS        F        p
Depth        1    2.0074    2.0074    24.62    0.000
ERROR     1145   93.3516    0.0815
TOTAL     1146   95.3590
```

```
                                        INDIVIDUAL 95 PCT CI'S FOR MEAN
                                        BASED ON POOLED STDEV
LEVEL      N      MEAN     STDEV  --------+---------+---------+--------
    5    592   -0.6088    0.2927  (-----*-----)
   25    555   -0.5251    0.2776                       (-----*-----)
                                   --------+---------+---------+--------
POOLED STDEV =   0.2855                 -0.600    -0.560    -0.520
MTB >
```

Appendix 2. Species lists for each primary (NR1, NR2, NR4 and NR5) and variance sample area (V1 = June 2, V2 = June 22, V3 = July 22, V4 = Sept. 13 and V5 = Oct. 30).

Common Name	Scientific Name	NR1	NR2	NR4	NR5	V1	V2	V3	V4	V5
Basswood	*Tilia americana L. (syn. T. glabra Vent.)*	*	*	*	*	*	*	*	*	*
Beech	*Fagus grandifolia Ehrh.*	*	*	*	*	*	*	*	*	*
Big Shellbark Hickory	*Carya laciniosa (Michx. f.) Loud.*			*						
Black Ash	*Fraxinus nigra Marsh.*		*							
Black Cherry	*Prunus serotina Ehrh.*	*	*	*	*					
Black Maple	*Acer nigrum Michx. f.*		*							
Black Walnut	*Juglans nigra L.*	*	*	*	*	*				*
Blue Beech	*Carpinus caroliniana Walt.*		*	*	*		*			
Choke Cherry	*Prunus virginiana L*		*	*	*		*			
Chinquapin Oak	*Quercus meuhlenbergii Engelm.*			*						
Common Buckthorn	*Rhamnus cathartica L.*		*							
Common Juniper	*Juniperus horizontalis L.*		*							
Domestic Apple	*Malus sylvestris L.*		*							
Eastern Flowering Dogwood	*Cornus florida L.*		*	*	*					
Eastern Hemlock	*Tsuga canadensis (L.) Carr.*	*	*							
Downy Hawthorn	*Crataegus mollis Schede*		*	*				*	*	
Hop Hornbeam	*Ostrya virginiana (Mill.) K. Koch*	*	*	*	*	*	*	*	*	*
Largetooth Aspen	*Populus grandidentata Michx.*		*	*	*					
Red Maple	*Acer rubrum L.*			*	*					
Red Oak	*Quercus rubra L.*	*	*	*	*	*	*	*	*	*
Sassafras	*Sassafras albidum (Nutt.) Nees (syn. S. variifolium (Salisb.) Ktze.)*			*						

Appendix 2 cont.

Common Name	Scientific Name	NR1	NR2	NR4	NR5	V1	V2	V3	V4	V5
Downy Juneberry (Serviceberry)	***Amelancheir arborea (Michx. f.) Fern***			*						
Shagbark Hickory	***Carya ovata (Mill.) K. Koch***	*	*	*	*	*	*	*	*	*
Slippery Elm	***Ulmus rubra Muhl. (syn. U. fulva Michx.)***		*		*					
Sour Cherry	***Prunus cerasus L.***			*						
Southern Arrow-wood	***Viburnum recognitum L.***	*	*		*					
Speckled Alder	***Alnus rugosa (Du Roi) Spreng.***			*						
Staghorn Sumac	***Rhus typhina L.***		*							
Sugar Maple	***Acer saccharum Marsh.***	*	*	*	*	*	*	*	*	*
White Ash	***Fraxinus americana L.***	*	*	*	*	*	*	*	*	*
White Birch	***Betula papyrifera Marsh.***	*	*	*						
White Elm	***Ulmus americana L.***	*	*	*						
White Oak	***Quercus alba L.***	*	*	*		*			*	*
White Pine	***Pinus strobus L.***		*		*					
Yellow Birch	***Betula alleghaniensis Britton (Syn. B. lutea Michx. f.)***		*	*						

Appendix 3. Relative density, dominance, frequency and importance values for tree and sapling species within sample areas.

1. Relative Density

a. Trees

Species	NR1		NR2		NR4		NR5	
	5 metres	**25 metres**	**5 metres**	**25 metres**	**5 metres**	**25 metres**	**5 metres**	**25 metres**
Fraxinus nigra			0.00	0.01				
Malus sylvestris			0.02	0.01				
Fraxinus americana	0.10	0.17	0.16	0.09	0.09	0.12	0.11	0.15
Carpinus caroliniana			0.01	0.00	0.01	0.00	0.02	0.00
Tilia americana	0.09	0.05	0.09	0.06	0.10	0.11	0.04	0.02
Fagus grandifolia	0.09	0.05	0.09	0.19	0.10	0.11	0.04	0.02
Carya laciniosa					0.004	0.00		
Rhamnus cathartica			0.01	0.00				
Betula papyrifera	0.01	0.00	0.01	0.01	0.004	0.004		
Betula alleghaniensis			0.00	0.01				
Prunus serotina	0.03	0.03	0.07	0.03	0.06	0.01	0.05	0.03
Prunus virginiana					0.00	0.004		
Prunus cerasus					0.004	0.00		
Cornus florida							0.00	0.01
Ulmus rubra			0.00	0.01				
Ulmus americana	0.01	0.00	0.03	0.01	0.00	0.01		
Tsuga canadensis	0.03	0.02	0.02	0.02				
Ostrya virginiana			0.11	0.10	0.10	0.02	0.17	0.13
Juniperus horizontalis			0.01	0.00				
Acer nigrum			0.00	0.01				
Acer saccharum	0.46	0.45	0.24	0.37	0.30	0.36	0.29	0.52
Acer rubrum					0.02	0.00		
Quercus meuhlenbergii					0.00	0.004		

Appendix 3 cont.

Species	NR1		NR2		NR4		NR5	
	5 metres	25 metres	5 metres	25 metres	5 metres	25 metres	5 metres	25 metres
Quercus rubra	0.08	0.02	0.03	0.03	0.07	0.06	0.05	0.05
Quercus alba	0.01	0.00	0.02	0.01	0.01	0.04		
Populus grandidentata			0.04	0.00	0.02	0.01	0.03	0.00
Pinus strobus							0.00	0.01
Sassafras albidum					0.00	0.004		
Carya ovata	0.11	0.03	0.04	0.02	0.03	0.03	0.14	0.01
Rhus typhina			0.00	0.01				
Juglans nigra			0.02	0.01	0.00	0.004	0.01	0.00

b. Saplings

Species	NR1		NR2		NR4		NR5	
	5 metres	25 metres	5 metres	25 metres	5 metres	25 metres	5 metres	25 metres
Alnus rugosa						0.004	0.00	
Malus sylvestris			0.01	0.01				
Viburnum recognitum							0.00	0.03
Fraxinus americana	0.14	0.10	0.08	0.02	0.03	0.02	0.08	0.00
Carpinus caroliniana			0.03	0.06	0.06	0.07	0.04	0.02
Tilia americana			0.04	0.02	0.03	0.01	0.02	0.03
Fagus grandifolia	0.10	0.24	0.11	0.27	0.30	0.40	0.07	0.24
Carya laciniosa					0.01	0.00		
Rhamnus cathartica			0.02	0.00				
Betula papyrifera					0.02	0.00		
Betula alleghaniensis					0.01	0.00		
Prunus serotina			0.01	0.00	0.004	0.00	0.01	0.00
Prunus virginiana			0.02	0.02			0.01	0.00
Prunus cerasus					0.00	0.00		

Appendix 3 cont.

Species	NR1		NR2		NR4		NR5	
	5 metres	25 metres	5 metres	25 metres	5 metres	25 metres	5 metres	25 metres
Cornus florida			0.02	0.02	0.004	0.00	0.00	0.01
Ulmus rubra			0.00	0.03			0.04	0.00
Ulmus americana			0.03	0.00				
Crataegus mollis			0.01	0.00	0.01	0.00		
Tsuga canadensis			0.01	0.02				
Ostrya virginiana	0.16	0.10	0.12	0.00	0.17	0.09	0.18	0.02
Acer saccharum	0.52	0.52	0.48	0.53	0.30	0.41	0.46	0.60
Acer rubrum					0.01	0.00		
Quercus rubra			0.00	0.01	0.02	0.00		
Pinus strobus			0.01	0.00				
Amelancheir arborea					0.01	0.00		
Carya ovata	0.06	0.03	0.01	0.00	0.00	0.004	0.09	0.01
Juglans nigra					0.00	0.00		

2. Relative Dominance

a. Trees

Species	NR1		NR2		NR4		NR5	
	5 metres	25 metres	5 metres	25 metres	5 metres	25 metres	5 metres	25 metres
Fraxinus nigra			0.00	0.004				
Malus sylvestris			0.01	0.002				
Fraxinus americana	0.03	0.16	0.12	0.15	0.12	0.15	0.08	0.24
Carpinus caroliniana			0.004	0.00	0.01	0.00	0.01	0.00
Tilia americana	0.07	0.04	0.10	0.04	0.07	0.08	0.08	0.02
Fagus grandifolia	0.07	0.19	0.11	0.25	0.14	0.17	0.07	0.05
Carya laciniosa					0.01	0.00		
Rhamnus cathartica			0.001	0.00				

Appendix 3 cont.

	NR1		NR2		NR4		NR5	
Species	**5 metres**	**25 metres**	**5 metres**	**25 metres**	**5 metres**	**25 metres**	**5 metres**	**25 metres**
Betula papyrifera	0.01	0.00	0.001	0.02	0.002	0.002		
Betula alleghaniensis			0.00	0.01				
Prunus serotina	0.01	0.02	0.05	0.03	0.07	0.004	0.03	0.02
Prunus virginiana					0.00	0.01		
Prunus cerasus					0.001	0.00		
Cornus florida							0.00	0.001
Ulmus rubra			0.00	0.002				
Ulmus americana	0.01	0.00	0.01	0.01	0.001	0.01		
Tsuga canadensis	0.06	0.00						
Ostrya virginiana			0.06	0.03	0.04	0.01	0.05	0.04
Juniperus horizontalis			0.00	0.00				
Acer saccharum	0.45	0.49	0.18	0.29	0.35	0.30	0.48	0.47
Acer rubrum					0.01	0.00		
Quercus muehlenbergii					0.00	0.003		
Quercus rubra	0.17	0.08	0.12	0.10	0.13	0.18	0.09	0.10
Quercus alba	0.03	0.00	0.11	0.01	0.01	0.06		
Populus grandidentata			0.03	0.00	0.02	0.01	0.03	0.00
Pinus strobus			0.003	0.00			0.00	0.03
Sassafras albidum					0.00	0.003		
Carya ovata	0.11	0.01	0.03	0.02	0.02	0.02	0.10	0.01
Rhus typhina			0.00	0.001				
Juglans nigra			0.05	0.03			0.003	0.00

Appendix 3 cont.

b. Saplings

	NR1		NR2		NR4		NR5	
Species	**5 metres**	**25 metres**	**5 metres**	**25 metres**	**5 metres**	**25 metres**	**5 metres**	**25 metres**
Alnus rugosa					0.01	0.00		
Malus sylvestris			0.01	0.03				
Viburnum recognitum			0.004	0.00			0.00	0.03
Fraxinus americana	0.13	0.09	0.08	0.02	0.04	0.01	0.12	0.00
Carpinus caroliniana					0.06	0.07	0.05	0.06
Tilia americana			0.06	0.03	0.02	0.01	0.01	0.02
Fagus grandifolia	0.12	0.17	0.13	0.25	0.29	0.38	0.10	0.21
Carya laciniosa					0.01	0.00		
Rhamnus cathartica			0.04	0.00				
Betula papyrifera					0.01	0.00		
Betula alleghaniensis					0.01	0.00		
Prunus serotina			0.02	0.00	0.01	0.00	0.01	0.00
Prunus virginiana			0.01	0.00				
Prunus cerasus					0.01	0.00		
Cornus florida			0.01	0.02	0.01	0.00		
Ulmus rubra			0.00	0.05			0.05	0.00
Ulmus americana	0.00	0.05	0.04	0.00				
Crataegus mollis			0.01	0.00	0.02	0.00		
Tsuga canadensis			0.00	0.03				
Ostrya virginiana	0.16	0.09	0.13	0.00	0.22	0.10	0.17	0.03
Acer saccharum	0.52	0.59	0.46	0.58	0.27	0.43	0.41	0.69
Acer rubrum					0.01	0.00		
Quercus rubra					0.01	0.00		
Pinus strobus			0.004	0.00				
Amelancheir arborea					0.01	0.00		
Carya ovata	0.06	0.01	0.01	0.00	0.00	0.01	0.10	0.00
Juglans nigra	0.02	0.00			0.01	0.00		

Appendix 3 cont.

3. Relative Frequency

a. Trees

Species	NR1		NR2		NR4		NR5	
	5 metres	25 metres	5 metres	25 metres	5 metres	25 metres	5 metres	25 metres
Fraxinus nigra			0.00	0.01				
Malus sylvestris			0.02	0.01				
Fraxinus americana	0.13	0.20	0.20	0.10	0.11	0.14	0.12	0.19
Carpinus caroliniana			0.02	0.00	0.01	0.00		
Tilia americana	0.13	0.08	0.09	0.09	0.11	0.13	0.07	0.04
Fagus grandifolia	0.62	0.23	0.08	0.20	0.16	0.17	0.07	0.09
Carya laciniosa					0.01	0.00		
Rhamnus cathartica			0.01	0.00				
Betula papyrifera	0.02	0.00	0.01	0.02	0.01	0.01		
Betula alleghaniensis			0.00	0.01				
Prunus serotina	0.04	0.05	0.08	0.05	0.08	0.01	0.07	0.04
Prunus virginiana					0.00	0.01		
Prunus cerasus					0.01	0.00		
Ulmus rubra			0.00	0.02				
Ulmus americana	0.02	0.00	0.05	0.02	0.01	0.01		
Tsuga canadensis	0.02	0.03						
Ostrya virginiana			0.10	0.09	0.11	0.03	0.15	0.15
Juniperus horizontalis			0.01	0.00				
Acer saccharum	0.33	0.38	0.20	0.30	0.24	0.29	0.22	0.37
Acer rubrum					0.01	0.00		
Quercus muehlenbergii					0.00	0.01		
Quercus rubra	0.08	0.03	0.04	0.05	0.07	0.08	0.08	0.07
Quercus alba	0.02	0.00	0.02	0.01	0.02	0.03		
Populus grandidentata			0.03	0.00	0.02	0.02		
Pinus strobus			0.01	0.00				
Sassafras albidum					0.00	0.01		

Appendix 3 cont.

Species	NR1		NR2		NR4		NR5	
	5 metres	25 metres	5 metres	25 metres	5 metres	25 metres	5 metres	25 metres
Carya ovata	0.15	0.03	0.05	0.04	0.05	0.05	0.15	0.12
Rhus typhina			0.00	0.01				
Juglans nigra			0.02	0.01	0.00	0.01		

b. Saplings

Species	NR1		NR2		NR4		NR5	
	5 metres	25 metres	5 metres	25 metres	5 metres	25 metres	5 metres	25 metres
Alnus rugosa					0.01	0.00		
Malus sylvestris			0.01	0.03				
Viburnum recognitum			0.01	0.00			0.00	0.10
Fraxinus americana	0.22	0.16	0.09	0.03	0.05	0.01	0.10	0.00
Carpinus caroliniana			0.04	0.07	0.08	0.05	0.08	0.03
Tilia americana			0.04	0.03	0.05	0.03	0.03	0.07
Fagus grandifolia	0.06	0.29	0.13	0.27	0.38	0.38	0.05	0.29
Carya laciniosa					0.02	0.00		
Rhamnus cathartica			0.03	0.00				
Betula papyrifera					0.03	0.00		
Betula alleghaniensis					0.01	0.00		
Prunus serotina			0.01	0.00	0.01	0.00	0.03	0.00
Prunus virginiana			0.03	0.00				
Prunus cerasus					0.01	0.00		
Cornus florida			0.03	0.03	0.01	0.00		
Ulmus rubra			0.00	0.03			0.08	0.00
Ulmus americana	0.00	0.04	0.03	0.00				
Crataegus mollis			0.01	0.00	0.01	0.00		

Appendix 3 cont.

Species	NR1		NR2		NR4		NR5	
	5 metres	25 metres	5 metres	25 metres	5 metres	25 metres	5 metres	25 metres
Tsuga canadensis			0.00	0.03				
Ostrya virginiana	0.19	0.11	0.13	0.00	0.17	0.12	0.20	0.07
Acer saccharum	0.41	0.39	0.39	0.46	0.24	0.39	0.36	0.45
Acer rubrum					0.04	0.00		
Quercus rubra					0.03	0.00		
Pinus strobus			0.01	0.00				
Amelancheir arborea					0.01	0.00		
Carya ovata	0.09	0.04	0.03	0.00	0.00	0.01	0.08	0.00
Juglans nigra	0.03	0.00			0.01	0.00		

4. Importance Value

a. Trees

Species	NR1		NR2		NR4		NR5	
	5 metres	25 metres	5 metres	25 metres	5 metres	25 metres	5 metres	25 metres
Fraxinus americana	0.25	0.53	0.48	0.34	0.32	0.41	0.31	0.58
Tilia americana	0.28	0.17	0.28	0.19	0.28	0.33	0.19	0.08
Fagus grandifolia	0.77	0.64	0.29	0.64	0.46	0.55	0.18	0.22
Prunus serotina	0.08	0.10	0.20	0.11	0.21	0.03	0.14	0.09
Acer saccharum	1.24	1.32	0.62	0.95	0.88	0.95	0.98	1.36
Quercus rubra	0.33	0.13	0.19	0.17	0.28	0.32	0.22	0.22
Carya ovata	0.37	0.07	0.12	0.07	0.10	0.10	0.39	0.04

Appendix 3 cont.

b. Saplings

Species	NR1		NR2		NR4		NR5	
	5 metres	**25 metres**	**5 metres**	**25 metres**	**5 metres**	**25 metres**	**5 metres**	**25 metres**
Fagus grandifolia	0.28	0.70	0.25	0.79	0.98	1.17	0.15	0.73
Acer saccharum	1.45	1.51	1.33	1.57	0.81	1.24	1.22	1.72